PRODUCT ENGINEERING

JUNE, 1948

IN THIS ISSUE—Service Testing Consumer Products + Patent Fundamentals + Curie Temperature Alloys + Electrical Slip Rings and Brushes + 615 Aluminum Alloy

A McGRAW-HILL PUBLICATION

Revised...

AT YOUR FINGERTIPS

Standard Designations and Chemical Composition Ranges for Heat and Corrosion Resistant Castings have been revised by the Alloy Casting Institute. The chart below puts all this data conveniently

DESIGNATION	Co... tion —							
	C	Mn max.	Si	P max.	S ... max.	...r	Ni	Other Elements
CA-15	0.15 max.	1.00	1.50	0.04	0.04	...4	1 max.	Mo 0.5 max.†
CA-40	0.20-0.40	1.00	1.50	0.04	0.04	1...	1 max.	Mo 0.5 max.†
CB-30	0.30 max.	1.00	1.00	0.04	0.04	18-2...	...max.	—
CC-50	0.50 max.	1.00	1.00	0.04	0.04	26-30	4 m...	—
CE-30	0.30 max.	1.50	2.00	0.04	0.04	26-30	...-...	—
CF-8	0.08 max.	1.50	2.00	0.04	0.04	18-21	8-11	—
CF-20	0.20 max.	1.50	2.00	0.04	0.04	18-21	8-11	—
CF-8M	0.08 max.	1.50	1.50	0.04	0.04	18-21	9-12	Mo 2.0-3.0
CF-12M	0.12 max.	1.50	1.50	0.04	0.04	18-21	9-12	Mo 2.0-3.0
CF-8C	0.08 max.	1.50	2.00	0.04	0.04	18-21	9-12	Cb 8xC min., 1.0 max.
CF-16F	0.16 max.	1.50	2.00	0.17	0.04	18-21	9-12	Mo 1.5 max., Se 0.20-0.35
CF-16Fa	0.16 max.	1.50	2.00	0.04	0.20-0.40	18-21	9-12	Mo 0.40-0.80
					...04	20-23	10-13	—
					...04	22-26	12-15	—
					...04	22-26	12-15	—
					...04	23-27	19-22	—
					...04	26-30	4 max.	Mo 0.5 max.†
					...04	26-30	4-7	Mo 0.5 max.†
					...04	26-30	8-11	Mo 0.5 max.†
					...04	18-23	8-12	Mo 0.5 max.†
					...04	24-28	11-14	Mo 0.5 max.† N 0.2 max.
					...04	26-30	14-18	Mo 0.5 max.†
					...04	24-28	18-22	Mo 0.5 max.†
HU	0.35-0.75	2.00	2.50	0.04	0...			
HW	0.35-0.75	2.00	2.50	0.04	0...			
HX	0.35-0.75	...00	2.50	0.04	0...			

USE THIS HANDY GUIDE

It provides concise data to help you select alloy castings for use under conditions of elevated temperature, severe corrosion, or both. Use the chart when ordering or specifying Nickel-Chromium-Iron alloy castings. Copies are available on request . . . mail the coupon now.

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FRONT COVER—A special machine devised to test rear bicycle wheel assemblies by simulating acceleration, coasting, turning and braking periods under rider load. Courtesy of Sears, Roebuck and Co.

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IN THIS ISSUE

Service Testing Improves Consumer Products

Public demand for products that incorporate new materials and improved designs place an extra burden on the manufacturer. For high volume-low cost production, the manufacturer also must be assured of consumer acceptance. On page 81, M. A. Blu, in charge of Tool and Production Engineering, Sears, Roebuck and Co., tells how Sears tests consumer products and works with manufacturers to improve their designs. Desirable design objectives are listed.

Patents and the Engineer

One of the most misunderstood subjects in the engineering profession is patent protection. This is reflected in both kinds of mistaken attitudes: Extreme secrecy, and complete lack of record keeping. Beginning on page 113, H. A. Toulmin, Jr., nationally known patent attorney, presents the first part of a special report on patents and the protection of invention. Specific patent procedure is included, giving method of preparing the claims, specifications and drawings. The second and final part of this report will appear in the July issue.

Curie Temperature Alloys

Magnetic alloys sensitive to temperature changes have been used extensively to regulate magnetic output, and thus to control electrical performance. But applications have been few. On page 158, John Shaw, research and development department, International Nickel Co., presents data which are charted to enable the designer to select and apply this useful property of many alloys.

Gear Motors Based on Unit Design

Many factors must be studied in the development of any standardized manufactured product. W. P. Schmitter of The Falk Corporation, see page 153, presents the factors that influenced the design of a line of motor reducers around a basic unit.

Fungicide for Cork

Cork-faced laminated gaskets are attacked by fungus growths, even in temperate climates. On page 107, C. D. Cook and Robert Harrington, General Electric Company, give experimental data showing that salicylanilide, which is not corrosive, gives better protection against six types of fungi that attack cork than the beta napthol formerly used.

Shop Run Tolerances—II

Incomplete tolerance specifications can lead to manufacturing troubles. An otherwise satisfactory design can prove to be impractical and uneconomical by overlooking such things as eccentricity, squareness and fractional dimensions. On page 141, L. M. Nielsen of the General Electric Company in the final part of a series, gives acceptable tolerance data for dimensions of parts produced on screw machines. Tolerance specifications for parts produced on general machine shop equipment are also included.

Information from Brittle Coating—I

Previously brittle coatings have been used principally as stress detectors. A. J. Durelli, Armour Research Foundation, shows how brittle coatings can be used as a fairly complete method of stress analysis. Charts, formulas, and calculations for evaluating coating patterns begin on page 86.

Characteristics of 61S Aluminum Alloy Sheet

In comparison with higher strength aluminum sheet materials, 61S appears to be little known, but it possesses a unique combination of engineering and fabricating characteristics. Joseph J. Warga, development engineer, Kimble Division Owens-Illinois Glass Company, see page 108, discusses the engineering properties of 61S sheet, its resistance to corrosion, and its welding and forming characteristics.

Reinforced Plastic Joints—II

A popular misconception concerning plastics is that they can be machined and joined exactly like conventional materials. On page 134, Richard J. Francis, consulting engineer, goes on from the simple joints presented last month to discuss more complicated joints.

Rotating Electrical Contacts

Usually the problem in moving electrical contacts is to reduce the voltage drop, but not so when you are using slip rings and brushes as part of a strain gage circuit. Here, accuracy is best when the resistance of the moving contact stays the same throughout the test. On page 129, Messrs. Francis J. Dutee, Franklyn W. Phillips, and Richard H. Kemp of Aircraft Engine Research Laboratory, NACA compare the resistance behavior of 24 combinations of slip rings and brushes.

Electroplate Thickness Standards

Designers are often faced with the problem of specifying electroplate thicknesses to conform to armed services requirements or to those recommended by the American Society for Testing Materials. In an effort to clarify the situation, George Black presents on page 165, various standards set up for zinc and cadmium electroplates.

JULY HIGHLIGHTS

LIGHT ALLOYS NEED NEW DESIGN CONCEPTS. J. A. Gregoire, a leading European designer gives his ideas on improving mechanical construction. He calls for a complete break from the traditional method of merely substituting aluminum alloy for steel.

INDUSTRIAL SOLENOIDS, by Charles R. Underhill, consulting engineer. Basic characteristics of coil-and-plunger solenoids and how to modify them.

SEVEN BASIC METHODS FOR NON-DESTRUCTIVE TESTING OF MATERIALS, by Benson Carlin, Sperry Products, including comparison chart of operating characteristics.

BACKLASH CONSIDERATIONS WHEN DESIGNING GEARS, by Louis D. Martin, gear engineer, Eastman Kodak Co. Presents basic design and economic factors that should be considered when specifying backlash. Purpose of backlash and applications of zero backlash gears.

Human Factors in Design Programs

AS STATED by Walter P. Schmitter, chief engineer of The Falk Corporation in his article in this issue, product development must be an integrated program of design, production, purchasing and sales if the best results are to be achieved. This however is not a mere formula, nor can true cooperative effort result from only management directives. Human elements are the determining factors in the success or failure of any program requiring teamwork.

Two human failings that, above all others, can hamper or even wreck teamwork are refusal to acknowledge errors and loud condemnation of the individual who makes a mistake. The former is known by the slang term of "passing the buck," the latter is often called a "bawling out." Neither are constructive under any circumstances. Both are largely under the control of the directing head of the enterprise.

Buck passing is always in a downward direction. It is seldom possible to pass the buck to the boss. When a man goes on record to blame one of his subordinates for an error, three people are immediately involved: the top man, the blamer, and the blamed. Obviously, if the top man will take the time to do so, he can bring together in an open hearing all the individuals involved and thereby quickly and accurately place the responsibility where it belongs and forthrightly condemn those who had tried to evade their responsibility. Such a procedure is a strong deterrent to those who might be tempted to unshoulder their mistakes on someone else. Rarely will they try it a second time.

If an organization operates firmly on the principle that "the authority to issue an order carries with it the responsibility of seeing to it that it is properly executed," there will usually be few arguments as to who is to blame.

Unfortunately, only too often too much wrong emphasis is placed on errors and failure. Mistakes caused by carelessness, inattention and laziness should, of course, be condemned. But in engineering design in particular, many of the errors or failures are of a constructive nature and came about simply because of a lack of knowledge. Such failures become building blocks of progress. Perhaps some of them could be avoided. Even so, to berate a man publicly or privately for having made a mistake is often unjust and almost invariably breeds ill feeling, unconfidence, disloyalty. From such demoralization springs many other ills—including buck passing.

Real teamwork cannot be achieved by organization charts and management directives. It can only be when there is an atmosphere of mutual respect, honesty of purpose and charitable understanding of human limitations. It pays to be nice.

G. F. Nordenholt

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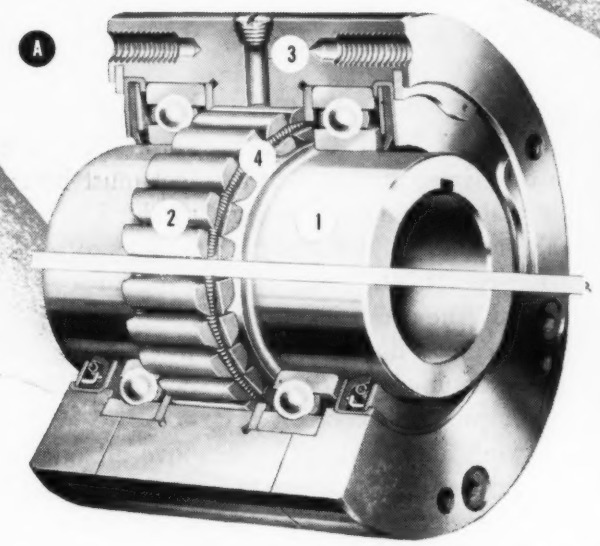

1. Inner Member 2. Sprag 3. Housing 4. Energizing Spring

A new principle in clutches . . .

BORROWING an idea from the wooden sprag that oldtimers used to prevent wagons from rolling backward, yet allowing free forward motion — Morse-Formsprag Clutches have come forth with the ultimate in Over-Running Clutch design.

Each Morse-Formsprag Clutch contains a full complement of sprags between inner member and housing. Contact between sprags is maintained by a circular pressure spring which acts as an energizing medium.

Because of the full complement of sprags used in Morse-Formsprag Clutches, localized stress is minimized. This design simplicity permits the greatest possible torque capacity for size and weight.

Three types of Morse-Formsprag Over-Running Clutches are available from stock—for indexing, over-running or backstopping:

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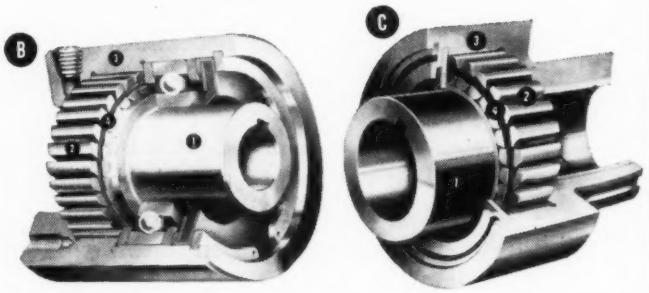
C. Plain-Bearing Type.

These three types are carried in stock with a variety of finished stock bores ready for immediate use. Special sizes and designs can be furnished to fit your requirements.

For detailed information, installation suggestions and ordering data, write Dept. 187 for Morse-Formsprag Catalog C11-42. Address: Morse Chain Company, 7601 Central Avenue, Detroit 8, Michigan.



1. Inner Member 2. Sprag 3. Housing 4. Energizing Spring

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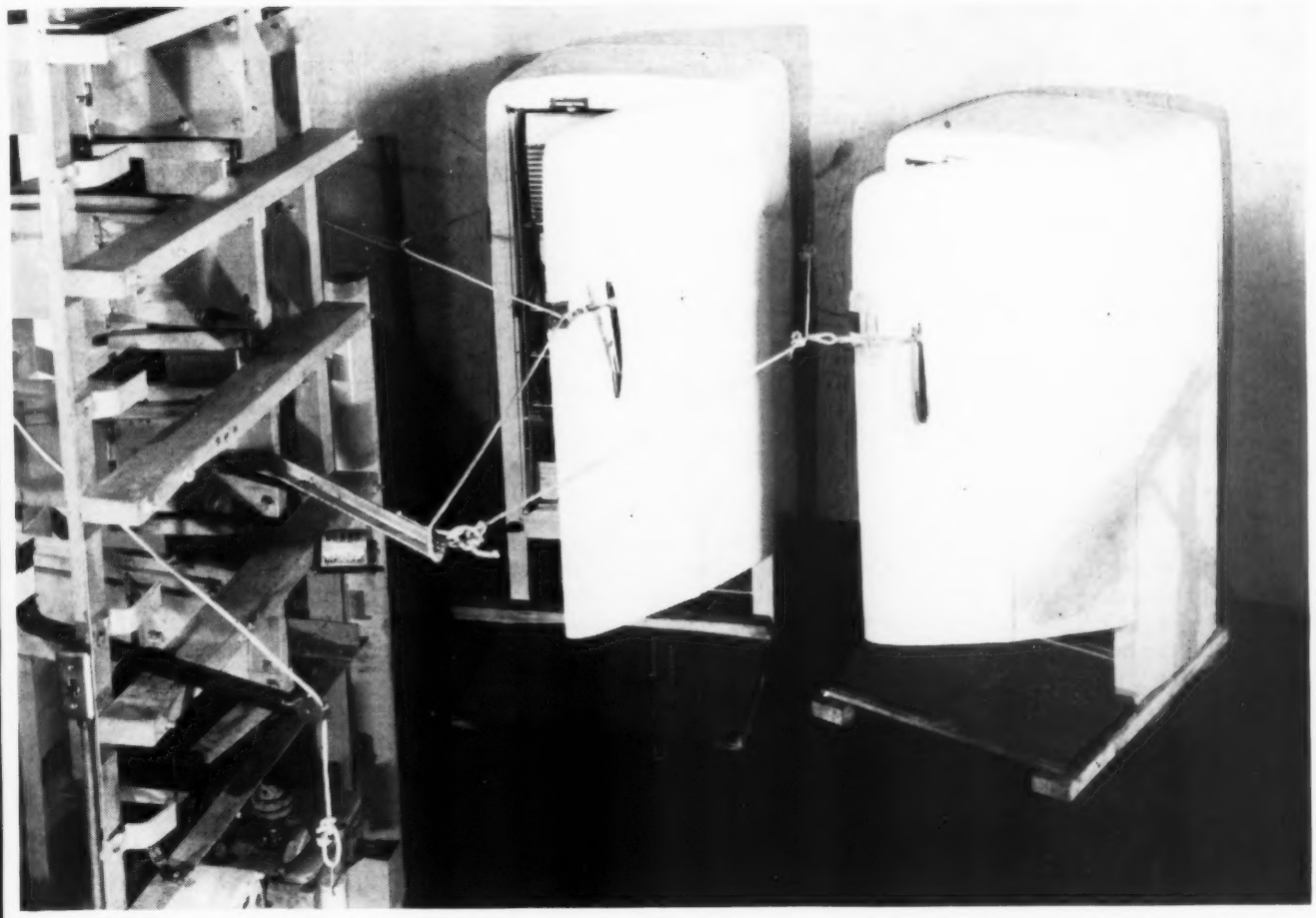

Fig. 1—Testing the performance of refrigerator hardware. The doors are opened and closed 20 times each minute for 36 working days, representing 20 years of normal operation. Hardware components that fail during this service test are redesigned.

Testing Consumer Products

The present day buying public has been led to believe that new materials, improved designs and revolutionary processes will be incorporated in new consumer goods. To create a product that is functionally sound, and to have reasonable assurance of customer acceptance of commercially unproven designs, thorough testing under simulated field conditions is essential.

M. A. BLU

In Charge of Tool & Production Engineering
Sears, Roebuck and Co.

ALTHOUGH MOST MANUFACTURERS have the usual test facilities, these are not always suitable for testing consumer products, such as household equipment, toys, electrical appliances and farm tools. Facilities also are provided by such organizations as the Underwriters' Laboratory and the American Gas Association, for final approval of the end product. But these organizations do not evaluate consumer acceptance, and generally they consider only the safety aspects of the product. A few manufacturers have developed the specialized equipment and assembled qualified personnel to conduct the many intermediate tests for evaluation of new materials, designs and processes before their acceptance and use in the finished product. However, not many companies are justified economically in establishing extensive facilities for a well-rounded, functional testing program.

In recognition of this need for testing in product development, Sears, in 1911, created its Merchandise Testing Laboratories. These serve the merchandise organization and the family of manufacturers whose goods are sold or are under consideration for sale by Sears. The original chemical laboratory of 1911 now has grown to include five other major testing divisions with a highly specialized staff of over a hundred technicians, divided among the chemical, mechanical, electrical, radio, home economics and textile divisions. Each has, in addition to standard test instruments, a varied assortment of special purpose equipment.

Tests are conducted in accordance with the published test codes and procedures of representative trade associations, specifications of federal bureaus, and standards established for the evaluation of basic materials. However, there is little such information in the field of consumers' goods, and it is necessary to formulate specific

test procedures for many items of merchandise.

General service facilities are maintained by the laboratory. These include a well-equipped machine shop, a technical library of approximately 5,000 books and some 15,000 scientific pamphlets and specifications. The library also circulates some 250 scientific journals and trade papers and maintains an indexing and abstracting service.

Test Procedures

Some problems require the facilities of only one division, but more frequently several divisions cooperate in the performance of a single test. If a complete evaluation of a vacuum cleaner were required, for example, the textile division would measure the air permeability of the bag and its resistance to wear; the chemical division would check the plating on metal parts and the suitability of plastic components; the home economics division would determine its ability to pick up dirt in practical tests and its convenience in use; the electrical division would investigate the amount of current leakage, the operation of the switch, the motor characteristics, the air delivery and its compliance with the safety requirements of the Underwriters' Laboratory; the mechanical division would study the life of the brush, belt, bearings and other parts, and the radio division would determine the degree of radio interference that its motor may cause.

Sometimes these tests go to extravagant lengths to obtain authoritative answers to specific problems. For example, the chemical division breeds cockroaches, flies and moths in the laboratory to permit positive evaluation of insecticides, fly sprays and moth repellents. Considerable research is being conducted by the entomological group on the problem of incorporating DDT in screen paint, cold water paint, and even in wallpaper. On this project it also is necessary to consider possible toxicity to human beings and to verify that the basic characteristics of the paint or other medium are preserved in the final product, along with the DDT's efficiency.

Standard test equipment is not always applicable to consumer products in their final form. Many special machines are constructed to test the functioning of a given device. To assist in the evaluation and design of bicycle coaster brakes, hubs, wheels and tires, the special test machine illustrated on the cover was built. This machine puts a rear bicycle wheel assembly through an automatic cycle comparable with the acceleration of the bicycle by a 180-lb rider to 15 mph in 6 sec, a coasting period of 30 sec, and brake application for a quick stop without skidding. During the coasting period the inertia drum in which the wheel rides, tilts in both

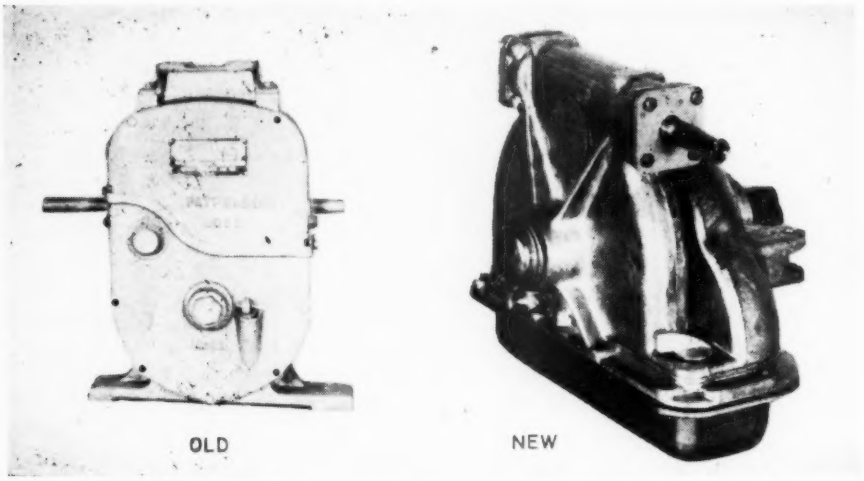

Fig. 2—(Left) The original stoker transmission, prior to five years of development and testing. (Right) The current stoker transmission which is far more efficient.

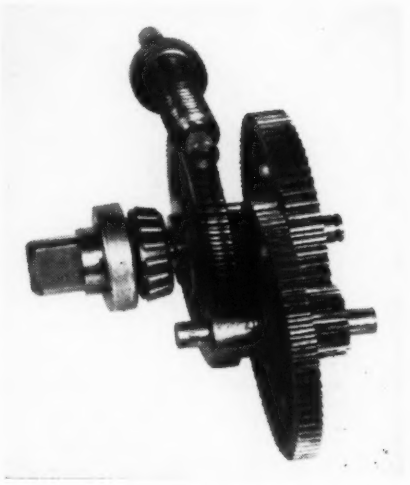

Fig. 3—The greatly simplified gear train which was developed for new transmission.

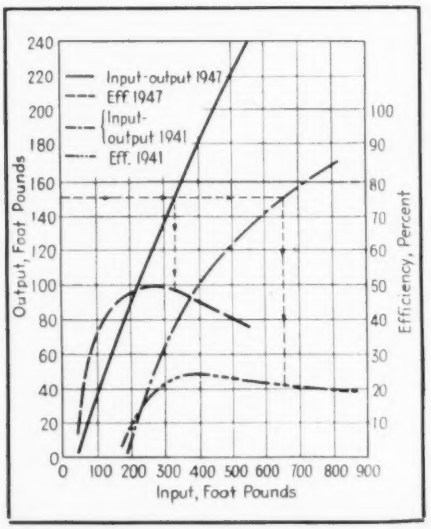

Fig. 4—Transmission performances of the 1941 and 1947 designs compared.

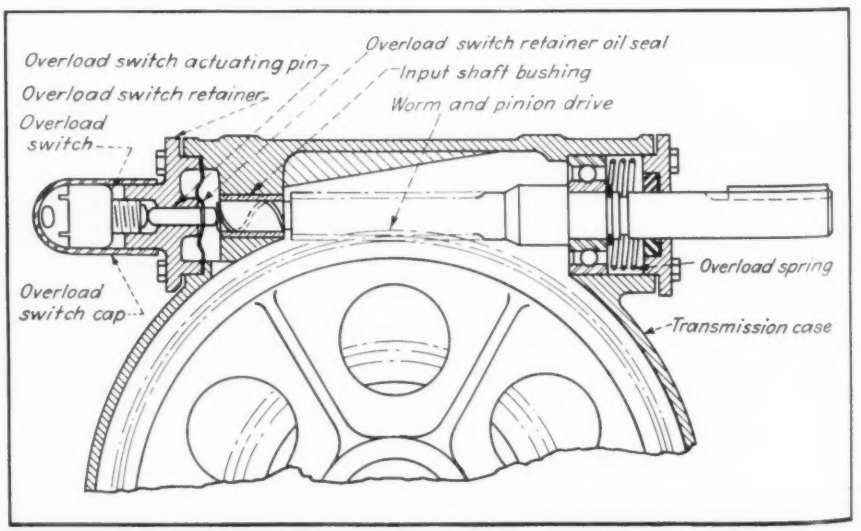

Fig. 5—Section through transmission drive and overload switch. Under overload, axial movement of worm gear and input shaft causes tripping of the overload switch.

directions to simulate turns around corners, thus placing side thrusts on the coaster bearings and other parts. Graphic records of the brake action can be taken at any time as the test progresses.

Another "Rube Goldberg" device, Fig. 1, is an arrangement for automatically opening and closing refrigerator doors with a force approximately equivalent to service conditions. These machines operate at 20 cpm, requiring 36 working days to verify the hardware performance. The refrigerator hardware must stand 350,000 cycles, representing 20 years of normal operation, assuming 50 closures per day. The refrigeration laboratory, with sealed humidity room and controlled temperatures, tests other phases of refrigerator performance.

A study of failures in a product's performance is passed back to the manufacturer for correction. The end result is that both the manufacturer and the Sears organization benefit by presenting a more serviceable product.

Testing the functional action of one part of a product is not always adequate. Typical of the painstaking efforts exerted in the laboratory to assure customer satisfaction is the investigation conducted on stoker transmission performance. Transmissions were tested, modified and retested over a period of five years in the development of the model currently being manufactured.

After a preliminary break-in period of 150 hours, each transmission was operated under conditions of maximum fuel speed rate for a period considered equivalent to five years of normal operation. Ten months of continuous testing were required to subject each transmission to this equivalent operation period. The test was conducted in a soundproof room isolated from the building structure by vibration dampers. This enabled sound level readings to be taken on both motor and transmission noise at the end of each equivalent year of operation. At the same time, the power consumption was checked and the oil was tested for sediment and was analyzed by chemical methods for metal particles and other evidences of breakdown.

After five equivalent years of operation under these most severe conditions, or upon the failure of any component, the transmission was disassembled and each part was examined for evidence of wear, misalignment, or other incipient failure.

These tests have resulted in a smaller, lighter, less expensive transmission with superior performance and life. Fig. 2 shows the original stoker transmission (left) and (right) the final stoker transmission. Fig. 3 illustrates the gear train, which has been greatly simplified. Evidence of improved transmission characteristics is shown by the Fig. 4 graph. The drawing, Fig. 5, illustrates the sensitive switch developed to disconnect the power in case of overloads. The new switch replaces the old conventional shear pin type of mechanism. For any given output the starting thrust is higher than the running thrust. A time delay element was therefore

Organization of the Sears Merchandise Testing Laboratories

MECHANICAL DIVISION

Evaluates general mechanical products:
Tools and hardware; air conditioning, refrigeration, combustion, hydraulic agricultural and automotive equipment; optical and photographic goods, and guns and ammunition.

Typical products:
Compressors, power tools, building accessories, freezers, refrigerators, milk coolers, fans, blowers, humidifiers, stoves, heaters, furnaces, boilers, stokers, pumps, water softening equipment, engines, bicycles, farm implements, boats, optical equipment, photographic paper, film, and equipment.

CHEMICAL DIVISION

Conducts chemical analyses; bacteriological, entomological and pharmaceutical investigations; metallurgical and metallographic checks.

Evaluates merchandise made of leather, rubber, and plastic materials.

Representative products:
Cosmetics, drugs, adhesives, pasteurizers, moth compounds and insecticides, tires, shoes, paints and varnishes, disinfectants, garden seeds, fertilizers, soaps and detergents, waxes and polishes, and mildew and rot proofing compounds.

HOME ECONOMICS DIVISION

Contributes the homemaker's viewpoint on the functional design and performance of kitchen and laundry equipment and household appliances in general.

Typical projects:
Investigations of food preparation and packaging for frozen food storage, kitchen planning, conducts use tests of dishwashers, garbage disposal units, housewares, irons and ironers, washing machines, gas and electric ranges.

RADIO DIVISION

Responsible for the testing of all radio, phonograph and electronic equipment.

Included in these classifications are:
Loud speakers, antennae, tubes, batteries, radio test instruments, public address systems, recording equipment, communication systems, phonograph needles, pick-ups and record changers.

TEXTILE DIVISION

Fully equipped for identification of knitted, woven and felted fabrics, and for determination of washability, shrinkage, water resistance, strength, weight, and color fastness of textile materials. This includes apparel and non-apparel textiles, such as bedding, curtains, upholstery, tents, typewriter ribbons and fish lines; and such items as paper products, flexible plastic films, buttons and fasteners.

ELECTRICAL DIVISION

Investigates performance life and safety of electrical appliances, motors and motorized equipment.

Includes:
Electrical power tools, fans, food mixers, heating and cooking appliances, such as electric ranges, roasters, toasters, and waffle irons; automotive accessories, test instruments and battery chargers; infra-red lamps and ultra-violet ray generators; lighting equipment, electric fence controllers and arc welders.

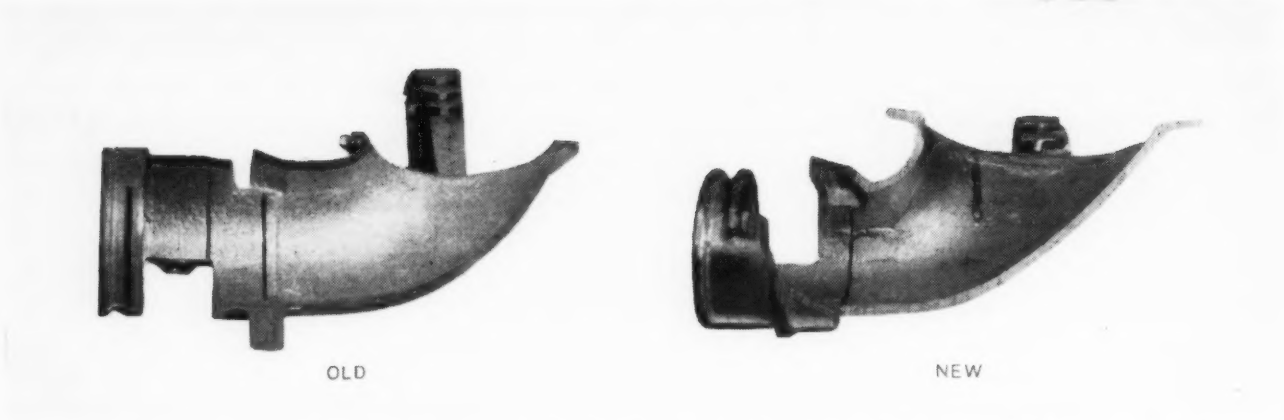

Fig. 6—Longitudinal cross-sections of old and new fire bowls. Change in tuyere height reduces "coke tree" formation. The retort throat curve has been changed for more even fuel distribution, also minimizing segregation of coarse and fine particles.

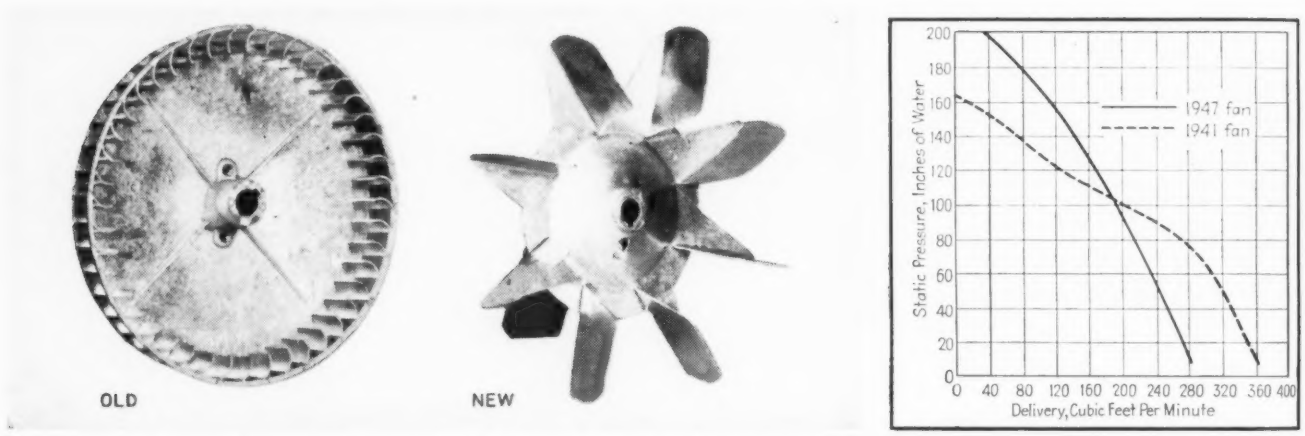

Fig. 7—Old and new blower fans compared. New fan is quieter and costs 10 percent less. (Right) In the operating range, the new design produces higher static pressure. Combustion equipment should be tested with fuel from different regions.

incorporated in the overload circuit and has proven to be particularly advantageous for instantaneous overloads, such as might occur if a large piece of coal became lodged in the coal chute. In other words, the transmission is now given an opportunity to work on the obstruction and to crush it, if possible, within a safe time limit.

The transmission was not the only component of the stoker to be improved. Fig. 6 shows the before-and-after shapes of the stoker fire bowl. Testing in the combustion laboratory indicated that modification of the old fire bowl was necessary to reduce "coke tree" formation with certain grades of coal and under certain firing conditions. By trial and error, the optimum area for the tuyeres was obtained. The height of the tuyeres and the fire bed area have been modified to promote uniformity of fuel bed conditions and the attendant fuel bed efficiencies. An obvious change is the curve and shape of the retort throat through which the coal passes to the burning area. The curve was modified so that there is now a more even distribution of new fuel over the entire fire bed. The new shape also minimizes segregation of coarse and fine coal particles.

Stoker combustion tests also exemplify a minor, yet important consideration with many products. The manufacturer must remember that his product may be sold in many parts of the country where operating conditions vary. This is particularly important on combustion equipment using coal. Therefore, the combustion laboratory tests all coal burning equipment with coal of different grades, brought from various coal areas in the United States.

The blower fan for the stoker also came in for redesign attention. Fig. 7 shows the original and improved version. Performance has been increased by changing the shape of the blades. The chart in Fig. 7 shows how the new fan delivers higher static pressure within the operating range of the stoker. The new fan is considerably quieter, and there is approximately a ten percent cost reduction over the old blower design.

It is the policy of Sears-Roebuck to make their findings available to the manufacturer for the ultimate benefit of the purchaser, the manufacturer and Sears. Frequently Sears engineers go to the manufacturer's plant and study his processes, discuss with and assist his engineers in improving the design. In Fig. 8 are "before" and "after" cuts of a motor-driven farm pump jack. The pump jacks are set up in the laboratory and loaded to high pressures and heavy loads equivalent to 300 ft of pump rod. All the tests indicate that the new case will outperform the original cast iron jack. It can be seen that a wide bearing area is obtained inside the stamped case by spot-welding a reinforcing member to the interior. This illustrates graphically the possibilities of reducing weight and cost, and improving the life of an inexpensive mechanism subject to heavy-duty consumer service.

All product development has not been confined to such large objects as a pump jack or stoker. Sears has found it worthwhile to give design attention to such minute objects as phonograph needles. Fig. 9 shows two versions of improved needles that were developed in an effort to increase the damping qualities in the so-called scratch range. It was also found

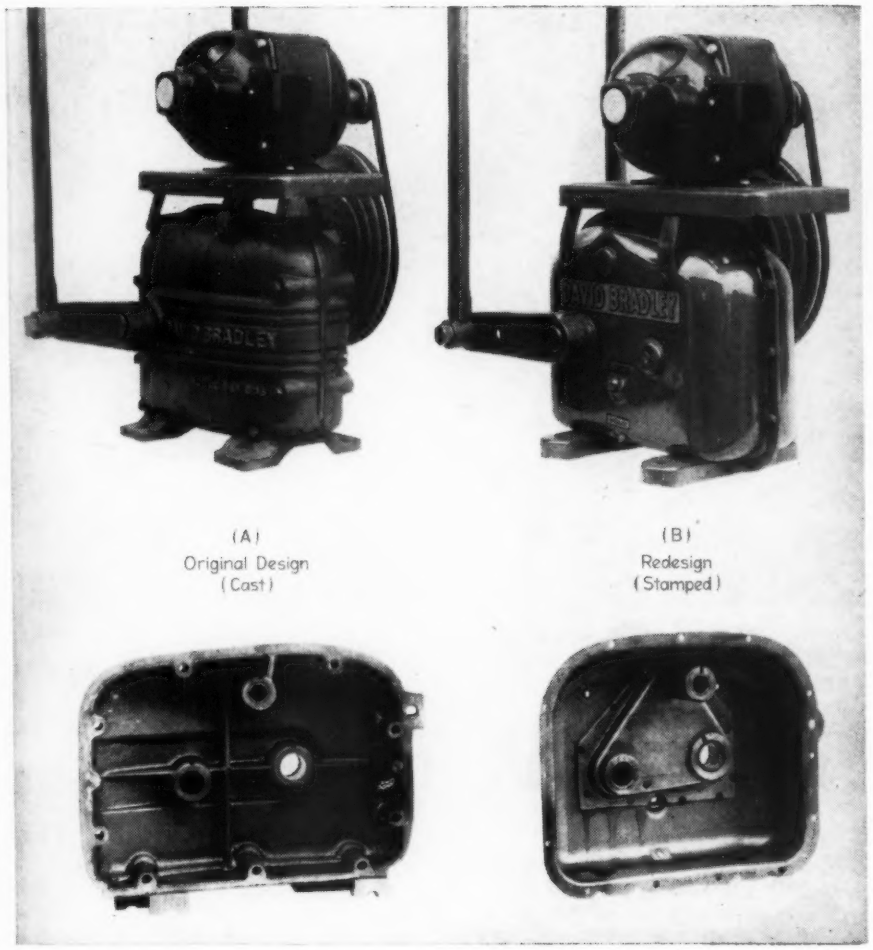

Fig. 3—Pump jack redesign. (Left) Heavy sections and ribs were required in old case. (Right) Bearing loads are distributed over a wide area by stamped reinforcement.

that the addition of these minute disks or flanges improved the fidelity in the five- to six-thousand cycle scratch zone. The size, diameter, and location of the disks were confirmed by trial and error experiments, working on the theory that the five- to six-thousand cycle range demanded certain positioning of the disks to neutralize vibrations within this region. The redesigned needle has improved fidelity and has less extraneous noise than any other needle we have ever tested. This is another evidence that a manufacturer can benefit from a thorough service testing of his product.

Simplified recording of tests and test results is essential for future reference and distribution of the basic information. Information from the test follows as far as possible an outline covering the statement of the problem, sample identification, methods used in testing, description of test apparatus, and test performance data, together with recommendations. These laboratory reports, with figures and charts, are supplied to our buyers and the development engineers of our sources of supply to aid in improving their merchandise along factual lines.

Thus trial and error development at the expense of the earlier customers is avoided and the experience gained in 35 years of consumers' goods testing is at the manufacturer's disposal.

In these years of testing, the laboratories have evolved a fairly concrete set of objectives for consumer products. Some of these are:

1. Every effort should be made to design durable equipment. In many cases our merchandise must carry a five-year guarantee.
2. Household appliances, especially those items that come into contact with foods, must be easy to clean, sanitary and corrosion resistant.
3. There should be a minimum of loose accessory parts.
4. The general public is posture conscious. The operator of any device must be afforded a comfortable position while operating.
5. Attractive appearance can be obtained without undue cost.
6. Portable items should be light weight.
7. Mechanisms involving power units or any kind of mechanical action should have a low noise level.
8. All devices using an electric current must not interfere with radios.
9. Outdoor items must be protected from corrosion and thoroughly tested to see that they operate well in weather conditions in any part of the country.
10. Forced lubrication is being applied to an ever-increasing number of farm appliances. This simplification of maintenance is a desirable objective for any consumer product.

These points may not apply to all items, but they do constitute a check list that will be useful to anyone who wishes to offer a low cost, reliable product to a broad consumer group.

Fig. 9—Two versions of an improved phonograph needle. The disks damp vibrations in 5,000-6,000 scratch range.

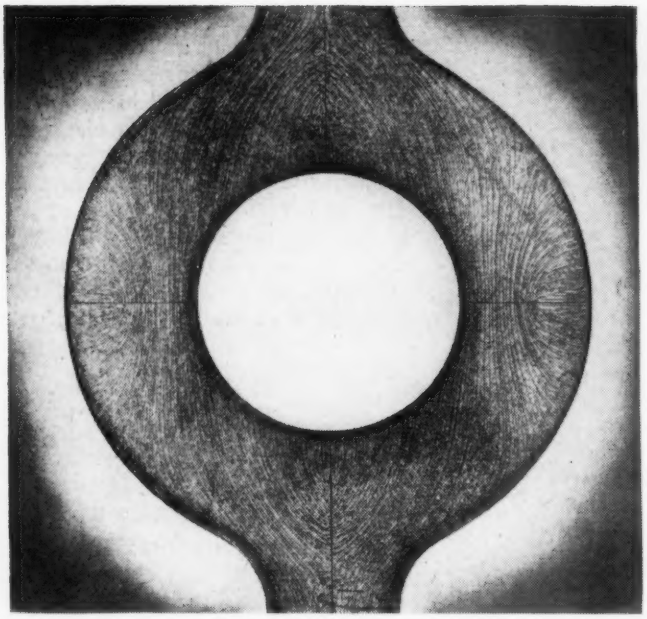

Fig. 1—Isostatics of family or set 1 as they appear on an eyebar loaded under tension. Obtained by loading the bar, applying the coating, then relaxing the load after drying.

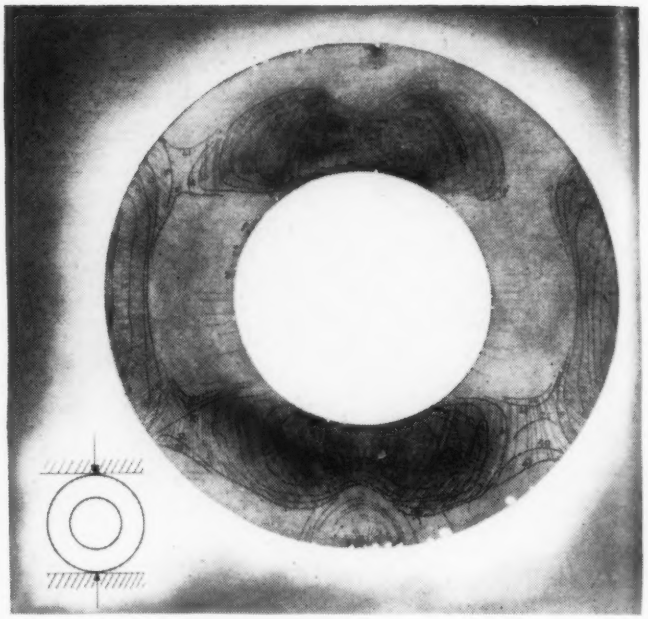

Fig. 2—Isoentatic ϵ_1 as obtained for a ring, from the direct load method.

What Kind of Information Does Brittle Coating Give?

PART I

Analysis of isostatic and isoentatic patterns in brittle coatings for different combinations of stresses. Formulas enabling the calculation of stresses with higher accuracy than that usually obtained. Coating failures not in accordance with the strain law. Use of refrigerating technique to obtain isostatics in zones where the strain is smaller than the strain sensitivity of the coating.

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BRITTLE COATINGS can be used as a quite complete method of stress analysis; a method able to attempt, in many cases, determination of the direction and the value of the two principal stresses at every point of a surface.

ISOSTATICS

First and most direct kind of information that brittle coatings give is the direction of the principal stresses. The lines of failure of the coating are isostatics, or trajectories of principal stresses; sometimes called less properly, stress trajectories. Direction of the principal stresses is on every point tangent and perpendicular to the isostatic on that point. These isostatics give not only directions of the principal stresses, but in some instances give the sign of the stresses, their relative magnitude, and for singular points, the necessary relation to calculate the principal stresses.

Isostatics may be obtained for all points of the surface using:

a. Direct method; loading after the coating has been applied and is dry.

b. Relaxation method; loading while the coating is wet and relieving the load after the coating is dry.

c. Refrigeration method; suddenly decreasing the temperature while the load is on the coated specimen. The coating then fails in zones where the strain is not quite high enough to crack it at room temperature.

Following properties of the brittle coating isostatic pattern are particularly useful:

A. Family or Set 1—obtained by relaxing the load. As shown in Fig. 1, set 1 is tangent at all points to the algebraically maximum principal strain and to the algebraically maximum principal stress. Family or Set 2—obtained by direct loading of the specimen. Set 2 is always tangent to the algebraically minimum principal strains and stresses as Fig. 2 shows. This can be proved physically by two facts: (1) Brittle coatings always crack perpendicularly to the maximum tensile strain that directly makes the coating break, (2) the direction of principal strain and stress coincide.

Tension and elongation are assumed as positive and compression and contraction as negative. When the relaxation method is used, all signs of stresses are reversed in the specimen; that is why set 1 is parallel to the maximum principal stress.

B. Since on free boundaries one principal stress is zero, it follows that on free boundaries belonging to family 1 the other principal stress is tensile, and on free boundaries belonging to family 2 that stress is compressive.

C. Moving along on isostatic from concave free boundaries toward the

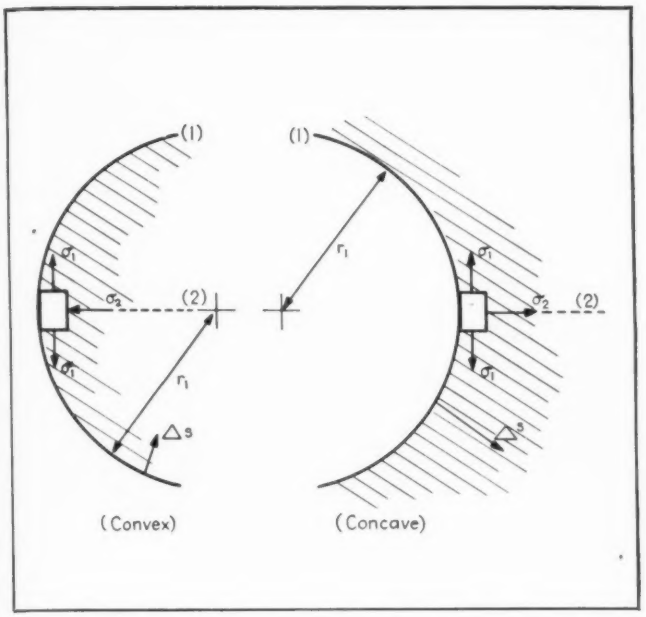


Fig. 3—Diagrammatic representation of the boundary condition of principal stresses in a coating for convex and concave edges.

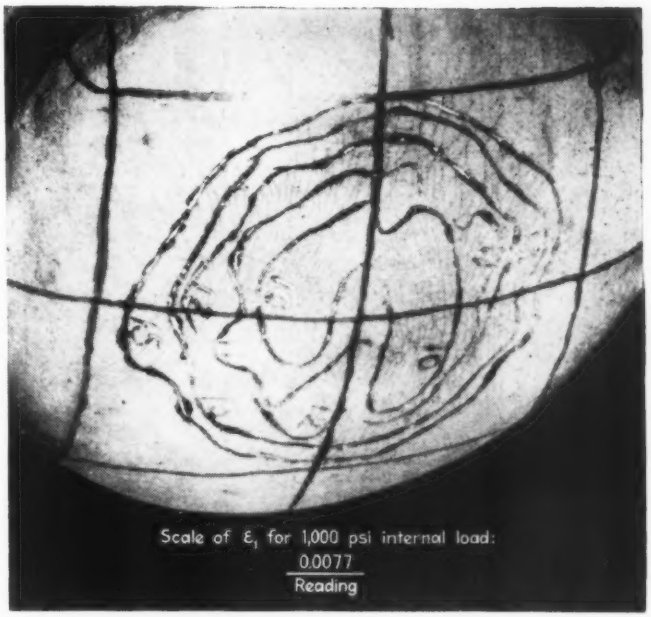


Fig. 4—Isostatics and isoentatics on the bottom of a pressure vessel which has a 1,000 psi internal hydraulic load.

field, both principal stresses will have the same sign near the boundary. Moving from convex free boundaries toward the field, both principal stresses have opposite signs. This was shown by Mesnager and can be easily demonstrated considering Lamé's formulas for the equilibrium of a curvilinear element; where σ_1 and σ_2 are the principal stresses, s_1 and s_2 elements of isostatics, and r_1 and r_2 radii of curvature of isostatics 1, 2, respectively

$$\frac{\delta\sigma_1}{\delta s_1} + \frac{\sigma_1 - \sigma_2}{r_2} = 0$$
$$\frac{\delta\sigma_2}{\delta s_2} + \frac{\sigma_1 - \sigma_2}{r_1} = 0 \qquad (1)$$

Let us assume that the boundary belongs to set 1. The principal stress σ_2 would be zero at the boundary itself, and we may assume that the value $\sigma_2 \neq 0$ is reached at a minute distance from the boundary by always increasing or always decreasing its value from zero.

$$\frac{\delta\sigma_2}{\delta s_2} = \frac{\sigma_2}{\Delta s_2} = \frac{\sigma_2 - \sigma_1}{r_1}$$
$$\sigma_2 = \sigma_1 \left(\frac{\Delta s_2}{r_1}\right) \Big/ \left(-1 + \frac{\Delta s_2}{r_1}\right)$$

When $\Delta s_2/r_1$ is negative (concave boundaries) both principal stresses have the same sign. When $\Delta s_2/r_1$ is positive (convex boundaries) both principal stresses have opposite signs as Fig. 3 reveals.

D. The principal stress along an isostatic reaches a maximum or a minimum value at intersection with another isostatic of the other family whose radius of curvature is infinite at the intersection. This follows from equation of equilibrium (1) by Lamé. When r_1 is infinite the term $(\sigma_1 - \sigma_2)/r_1$ is equal to zero. Therefore, $\delta\sigma_2/\delta s_2 = 0$ also, which means that σ_2 has a maximum or a minimum value.

Obviously this property also means that on free boundaries the principal stress reaches a maximum or a minimum when the boundary is intersected by an isostatic whose radius is infinite. The distinction between maximum and minimum is made by the sign of the stress, given by property B.

It also follows from (1) that when a free boundary is straight ($r_1 = \infty$), not only does $\sigma_2 = 0$, but $\delta\sigma_2/\delta s_2 = 0$, which means that the slope of the σ_2 is zero at the boundary.

E. Consider an isostatic belonging to the same family as the free boundary. The distance of this isostatic from the free boundary varies. The value of the boundary stress is inversely proportional to this distance.

The information given by a complete isostatic pattern may be better understood by referring again to Fig. 1. This shows an isostatic 1 in an eyebar, obtained by the relaxation of a tension load. On every point of the eyebar the maximum principal stress is tangent to the isostatic going through that point. The minimum principal stress is perpendicular to it (property A).

On the inside boundary, between singular points, where the isostatics of set 1 are parallel to the boundary, the stress is tensile. On the rest of that boundary where the isostatic set 1 is perpendicular to it, the stress is compressive.

On the outside boundaries, between singular points, the stress is compressive. The stress of the boundary is tensile from the singular point toward the straight part of the bar (property B).

On the horizontal axis the principal stress parallel to the axis and near both boundaries is tensile (property C).

The maximum or minimum value of this principal stress along the axis is reached at the point where an isostatic of set 1 intersects the axis under an infinite radius of curvature (property D). Since there is only one of these isostatics and since on the free boundary the other principal stress is zero, that value corresponds to a maximum.

On the boundaries, the stress is inversely proportional to the distance from the boundary to the first isostatic, running in its same direction (property E). This shows that the maximum principal stresses on the boundary are at the ends of the vertical and horizontal axis, in agreement with property D, since on those points the isostatics normal to the boundaries have an infinite radius of curvature.

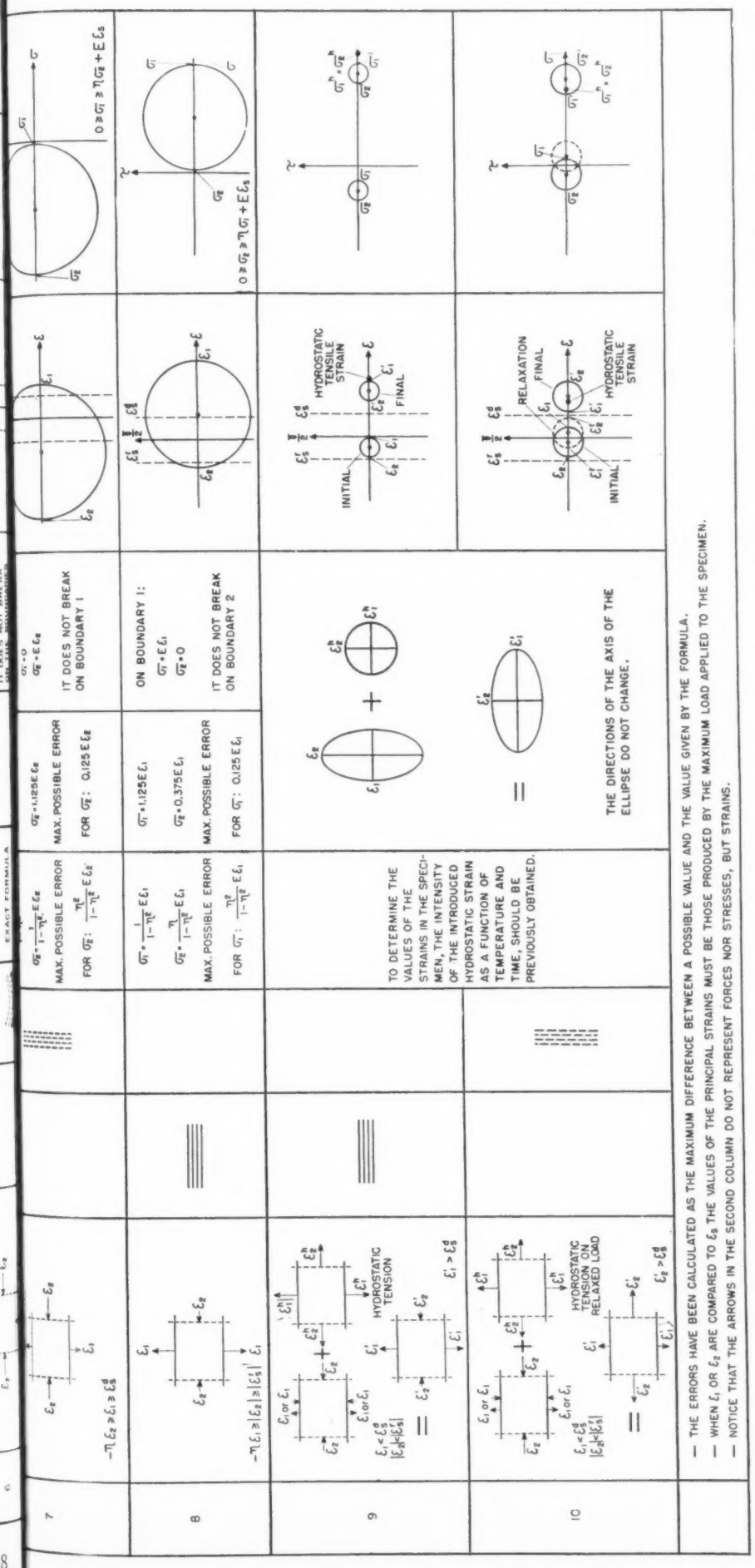
The accuracy of continuous isostatics obtained by means of brittle coatings is much higher than that obtained using photoelasticity or strain gages because both these methods require graphic interpolations from point to point, and the latter gives only average values for points within gage length.

Isoentatics

Although the law of failure of Stresscoat has not yet been determined definitely, it is generally assumed that

Table I - FORMULAS TO DETERMINE STRESS IN DIFFERENT ZONES OF BRITTLE COATING PATTERNS

ZONE	COMBINATION OF STRAINS $\varepsilon_1 > \varepsilon_2$ (+ ELONGATION, − CONTRACTION)	DIRECTION OF THE ISOSTATICS: σ_2 DIRECT LOADING (ISOENTATIC ε_1)	σ_1 BY RELAXATION (ISOENTATIC ε_2)	GENERAL FORMULA TO BE USED FOR σ_1 AND σ_2	FORMULA IN CASE POISSON'S RATIO = $\eta = \frac{1}{3}$	ON FREE BOUNDARIES — BOUNDARY 1: TENSION, BOUNDARY 2: COMPRES.	STRAIN CIRCLES	MOHR'S CIRCLES FOR $\eta = \frac{1}{3}$. RATIO OF ABSCISSAS OF STRAIN AND MOHR'S CIRCLES CENTERS = $\frac{1}{2}$.
1	a) b) c) d)	NO ISOSTATICS		$\frac{1}{1-\eta}E\varepsilon_3^r < \sigma_1 < \frac{1}{1-\eta}E\varepsilon_3^a$ $\frac{1}{1-\eta}E\varepsilon_3^r < \sigma_2 < \frac{1}{1-\eta}E\varepsilon_3^a$	$1.5E\varepsilon_3^r < \sigma_1 < 1.5E\varepsilon_3^a$ $1.5E\varepsilon_3^r < \sigma_2 < 1.5E\varepsilon_3^a$	ON BOUNDARY 1: $\sigma_2 = 0$ $0 < \sigma_1 < 1.5E\varepsilon_3^a$ $\sigma_1 \sim 0.75E\varepsilon_3^a$ ON BOUNDARY 2: $\sigma_1 = 0$ $0 > \sigma_2 > 1.5E\varepsilon_3^r$ $\sigma_2 \sim 0.75E\varepsilon_3^r$	a) b) c) d) $\varepsilon_1 = \varepsilon_2 = 0$	a) b) c) d) $\sigma_1 = \sigma_2 = 0$
2	a) b) $\varepsilon_1 > \varepsilon_3^a$ $\lvert\varepsilon_2\rvert > \lvert\varepsilon_3^r\rvert$			$\sigma_1 = \frac{1}{1-\eta^2}E\varepsilon_1$ $\sigma_2 = \frac{\eta}{1-\eta^2}E\varepsilon_1$ MAX. POSSIBLE ERROR FOR σ_1: $\pm\frac{\eta}{1-\eta^2}E\varepsilon_1$ FOR σ_2: $\pm\frac{1}{1-\eta^2}E\varepsilon_1$	$\sigma_1 = 1.125E\varepsilon_1$ $\sigma_2 = 0.375E\varepsilon_1$ MAX. POSSIBLE ERROR FOR σ_1: $\pm 0.375\,E\varepsilon_1$ FOR σ_2: $\pm$ 0.125$E\varepsilon_1$	ON BOUNDARY 1: $\sigma_1 = E\varepsilon_1$ $\sigma_2 = 0$ IT DOES NOT BREAK ON BOUNDARY 2 (SEE ZONE 8)	a) b)	a) b)
3	$\varepsilon_1 > \varepsilon_3^a$ $\varepsilon_2 = \varepsilon_1$			$\sigma_1 = \sigma_2 = \frac{E}{1-\eta}\varepsilon_1$ EXACT FORMULA	$\sigma_1 = \sigma_2 = 1.5E\varepsilon_1$	$\sigma_1 = \sigma_2 = 0$ IT DOES NOT BREAK ON THE BOUNDARIES	$\varepsilon_1 = \varepsilon_2$	$\sigma_1 = \sigma_2$
4	$\varepsilon_1 > \varepsilon_3^a$ $\lvert\varepsilon_2\rvert > \lvert\varepsilon_3^r\rvert$			$\sigma_1 = \frac{E}{1-\eta^2}(\varepsilon_1 + \eta\varepsilon_2)$ $\sigma_2 = \frac{E}{1-\eta^2}(\varepsilon_2 + \eta\varepsilon_1)$ EXACT FORMULA	$\sigma_1 = 1.125E(\varepsilon_1 + \frac{1}{3}\varepsilon_2)$ $\sigma_2 = 1.125E(\varepsilon_2 + \frac{1}{3}\varepsilon_1)$	NO FREE BOUNDARY IN THIS ZONE	c) b)	a) b)
5	a) b) $\lvert\varepsilon_2\rvert > \lvert\varepsilon_3^r\rvert$ $\varepsilon_1 < \varepsilon_3^a$ $\lvert\varepsilon_2\rvert > \lvert\varepsilon_3^r\rvert$			$\sigma_1 = \frac{\eta}{1-\eta^2}E\varepsilon_2$ $\sigma_2 = \frac{1}{1-\eta^2}E\varepsilon_2$ MAX. POSSIBLE ERROR FOR σ_1: $\pm\frac{1}{1-\eta^2}E\varepsilon_2$ FOR σ_2: $\pm\frac{\eta}{1-\eta^2}E\varepsilon_2$	$\sigma_1 = 0.375E\varepsilon_2$ $\sigma_2 = 1.125E\varepsilon_2$ MAX. POSSIBLE ERROR FOR σ_1: $\pm$ 0.125$E\varepsilon_2$ FOR σ_2: $\pm$ 0.375$E\varepsilon_2$	ON BOUNDARY 2: $\sigma_1 = 0$ $\sigma_2 = E\varepsilon_2$ IT DOES NOT BREAK ON BOUNDARY 1 (SEE ZONE 7)	a) b)	a) b)
6				$\sigma_1 = \sigma_2 = \frac{E}{1-\eta}\varepsilon_1$ EXACT FORMULA	$\sigma_1 = \sigma_2 = 1.5E\varepsilon_1$	$\sigma_1 = \sigma_2 = 0$ IT DOES NOT BREAK ON THE BOUNDARIES		
7				$\sigma_2 = \frac{1}{1-\eta^2}E\varepsilon_2$ MAX. POSSIBLE ERROR	$\sigma_2 = 1.125E\varepsilon_2$ MAX. POSSIBLE ERROR	$\sigma_1 = 0$ $\sigma_2 = E\varepsilon_2$		


MAX. POSSIBLE ERROR
FOR σ₂: 0.125 Eε₂
IT DOES NOT BREAK ON BOUNDARY 1
ON BOUNDARY 1:
IT DOES NOT BREAK ON BOUNDARY 2
MAX. POSSIBLE ERROR
FOR σ₁: 0.125 Eε₁
HYDROSTATIC TENSILE STRAIN
INITIAL
FINAL
RELAXATION
HYDROSTATIC TENSION
HYDROSTATIC TENSION OR RELAXED LOAD
TO DETERMINE THE VALUES OF THE STRAINS IN THE SPECIMEN, THE INTENSITY OF THE INTRODUCED HYDROSTATIC STRAIN AS A FUNCTION OF TEMPERATURE AND TIME, SHOULD BE PREVIOUSLY OBTAINED.
THE DIRECTIONS OF THE AXIS OF THE ELLIPSE DO NOT CHANGE.
— THE ERRORS HAVE BEEN CALCULATED AS THE MAXIMUM DIFFERENCE BETWEEN A POSSIBLE VALUE AND THE VALUE GIVEN BY THE FORMULA.
— WHEN ε₁ OR ε₂ ARE COMPARED TO ε_s THE VALUES OF THE PRINCIPAL STRAINS MUST BE THOSE PRODUCED BY THE MAXIMUM LOAD APPLIED TO THE SPECIMEN.
— NOTICE THAT THE ARROWS IN THE SECOND COLUMN DO NOT REPRESENT FORCES NOR STRESSES, BUT STRAINS.

the elastic characteristic defining the failure is the maximum tensile strain. Accepting this theory, brittle coatings under direct loading may give also the values of the principal strain for all points on the surface where this principal strain ϵ_1 (as explained under "property A") is an elongation and greater than the strain sensitivity ϵ^d_s of the coating for direct loading. By the relaxation method the value of the principal strain ϵ_2 is obtained for all points on the surface where ϵ_2 is a contraction, and greater than ϵ^r_s, the strain sensitivity for relaxation. (One exception to this rule will be mentioned later.) As used in these symbols, *d* and *r* are not exponents but identifications of direct-loading and relaxation-loading sensitivities.

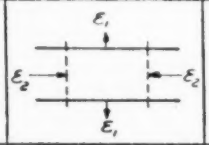
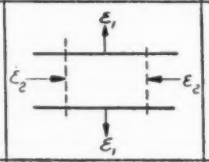
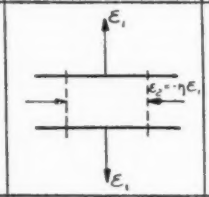
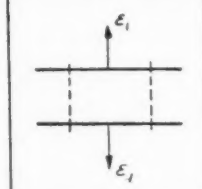
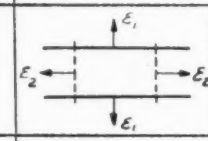
To determine the principal strains in a specimen, the load is applied in increments. After each increment of load a line (isoentatic) is drawn joining the ends of the cracks (isostatics). The drawn isoentatics are loci of points of equal principal strain (assuming the maximum tensile strain law of failure). The value of strain on each point of an isoentatic is inversely proportional to the value of the load at which it appeared; and is finally determined in absolute values by a calibration test giving ϵ_s, which is strain sensitivity of the coating that is used.

The bottom of a pressure vessel loaded internally with hydrostatic pressure is shown in Fig. 4. The grid of straight heavy lines was drawn to facilitate the location of the points on the 3-dimensional surface. The coating started cracking at 1,000 psi and the isostatics for that load were encircled by a line, No. 10, of equal principal strain, or isoentatic. When the load was increased to 1,100 psi, the cracked zone expanded and a new isoentatic, No. 11, was drawn. For 1,300 psi and for 1,500 psi, the same procedure was followed. The maximum load applied was 1,700 psi, but the isoentatic was not drawn for this value, so that the end points of the isostatics could be seen easily. The calibrating beam, sprayed and tested at the same time as the vessel, gave $\epsilon^d_s = 0.000\,77$. Taking the pressure 1,000 psi as a standard, the scale with which the figures of the pictures should be read to have the principal strain ϵ_1 on every point of an isoentatic is:

$$\frac{0.0077}{\text{reading}}$$

meaning by "reading" the number belonging to the isoentatic in Fig. 4. Each isoentatic pattern should have its

TABLE II - ANALYSIS OF FORMULAS USED FOR DETERMINATION OF THE PRINCIPAL STRESSES IN ZONE 2

	Combination of Strains	Value of the Stresses in Function of $\mathcal{E}_1$	Formulas when $\eta = \frac{1}{3}$
If $\mathcal{E}_2 > -\mathcal{E}_1$ there would be isostatics obtained by relaxation, in contradiction to definition of zone 2			
Pure Shear $\mathcal{E}_2 = -\mathcal{E}_1$ (limit case)		$\sigma_1 = -\sigma_2$ $= \frac{1}{1+\eta} E \mathcal{E}_1$	$\sigma_1 = 0.75\ E\ \mathcal{E}_1$ $\sigma_2 = -0.75\ E\ \mathcal{E}_1$
Uni-dimensional Tensile Stress (Pure Tension) $\mathcal{E}_2 = -\eta\ \mathcal{E}_1$		$\sigma_1 = E\ \mathcal{E}_1$ $\sigma_2 = 0$	$\sigma_1 = E\ \mathcal{E}_1$ $\sigma_2 = 0$
Uni-dimensional Tensile Strain $\mathcal{E}_2 = 0$		$\sigma_1 = \frac{1}{1-\eta^2} E \mathcal{E}_1$ $\sigma_2 = \frac{\eta}{1-\eta^2} E \mathcal{E}_1$	$\sigma_1 = 1.125\ E\ \mathcal{E}_1$ $\sigma_2 = 0.375\ E\ \mathcal{E}_1$
Singular Point $\mathcal{E}_2 = \mathcal{E}_1$ (limit case)		$\sigma_1 = \sigma_2$ $= \frac{1}{1-\eta} E \mathcal{E}_1$	$\sigma_1 = 1.5\ E\ \mathcal{E}_1$ $\sigma_2 = 1.5\ E\ \mathcal{E}_1$
By definition $\mathcal{E}_2$ cannot be greater than $\mathcal{E}_1$			

The arrows do not represent forces or stresses, but strains

own scale to be interpreted accurately.

The irregularities in the shape of the isoentatics may be caused by the following reasons: (a) Wall of non-uniform thickness, (b) dispersion in the value given by the brittle coating, (c) temperature gradient on the coating surface producing a change in the sensitivity of the coating. Error in the value of the isoentatics is greater than that for the isostatics, and may be up to 20 percent of the maximum strain.

Principal Stresses

Given the isostatic and isoentatic patterns, the principal stresses are calculated with different approximations for nine typical zones. By "zone" we mean a region with a defined isostatic pattern. Table I is a tabulation of the different cases, discussed below:

A. Zone 4

Principal stresses may easily be obtained for all points in zones where both principal strains were calculated from isoentatics of sets 1 and 2 (zone 4 of Table I) where $\eta =$ Poisson's ratio:

$$\epsilon_1 = \frac{\sigma_1}{E} - \frac{\eta\sigma_2}{E}$$

$$\epsilon_2 = \frac{\sigma_2}{E} - \frac{\eta\sigma_1}{E} \qquad (1)$$

therefore:

$$\sigma_1 = \frac{E}{1-\eta^2}(\epsilon_1 + \eta\,\epsilon_2) \qquad (2)$$

$$\sigma_2 = \frac{E}{1-\eta^2}(\epsilon_2 + \eta\,\epsilon_1)$$

and when $\eta = \frac{1}{3}$:

$$\sigma_1 = 1.125\ E\ (\epsilon_1 + \tfrac{1}{3}\,\epsilon_2) \qquad (3)$$

$$\sigma_2 = 1.125\ E\ (\epsilon_2 + \tfrac{1}{3}\,\epsilon_1)$$

B. Zones 3 and 6

It is also easy to determine the value of the principal stresses for all singular points (zones 3 and 6 in the table):

$$\epsilon_1 = \epsilon_2;\ \sigma_1 = \sigma_2$$

therefore:

$$\sigma_1 = E\,\epsilon_1 \frac{1+\eta}{1-\eta^2} = \frac{E}{1-\eta}\epsilon_1$$

and when

$$\eta = \tfrac{1}{3}:$$

$$\sigma_1 = 1.5\ E\ \epsilon_1$$

These formulas are exact, and the error of the value of σ_1 and σ_2 obtained is only a function of the dispersion of the value of the coating. Determination of a maximum principal stress, using the singular point relation, is given for the center of the bottom of the vessel shown in Fig. 4.

The isostatic pattern shows that the center of the vessel is a singular point; that is, the principal stresses are equal. The pattern is somewhat confused near this point because there is no preferential direction of stresses. If, in a whole zone such as the surface of a sphere internally hydrostatically loaded, the two principal stresses are equal, any extraneous influence makes the coating break following one direction instead of the other.

The formula to be used is, therefore (zone 3):

$$\sigma_1 = \frac{E}{1-\eta}\epsilon_1$$

and when $\eta = \frac{1}{3}$:

$$\sigma_1 = 1.5\ E\ \epsilon_1$$

Assuming $E = 20{,}000{,}000$ psi:

$$\sigma_1 = 30{,}000{,}000\ \epsilon_1$$

and since ϵ_1 for 1,000 psi is 0.00077:

$$\sigma_1 = \sigma_2 = 23{,}100 \text{ psi}$$

Since this is the highest stressed point, the real value of the stress concentration has been determined.

C. Zones 2 and 5

In zones 2 and 5 where only one family of isostatics can be obtained, it is customary to calculate the principal stress assuming a uni-dimensional state of stress; using the formulas

$$\sigma_1 = E\epsilon_1 \quad , \sigma_2 = 0.$$

States of strain corresponding to zone 2 are represented in the first and second columns of Table II. Let us keep ϵ_1 constant and vary ϵ_2. The smallest value of ϵ_2 in this zone is $\epsilon_2 = -\epsilon_1$ (pure shear) and the largest is $\epsilon_2 = \epsilon_1$ (singular point). Zone 2 includes all variations between pure shear and singular point conditions. For pure shear $\sigma_1 = 1/(1+\eta)\ E\epsilon_1 = 0.75\ E\epsilon_1$ (for $\eta = \frac{1}{3}$) corresponding to the minimum value. The largest value of σ_1 is for a singular point $\sigma_1 = 1/(1-\eta)\ E\epsilon_1 = 1.5\ E\epsilon_1$ (for $\eta = \frac{1}{3}$).

As long as σ_1 is unknown, the most probable value for σ_1 where η equals $\frac{1}{3}$ is:

$$\sigma_1 = \frac{\sigma_{max} + \sigma_{min}}{2}\,\frac{1}{1-\eta^2}\,E\,\epsilon_1 = 1.125\,E\,\epsilon_1$$

The maximum value for the error is:

$$\text{error} = \frac{\sigma_{max} - \sigma_{min}}{2} = \frac{\eta}{1-\eta^2} E \epsilon_1 = 0.375\ E\ \epsilon_1$$

The result is, therefore:

$$\sigma_1 = \frac{1}{1-\eta^2} E \epsilon_1 \pm \frac{\eta}{1-\eta^2} E \epsilon_1$$

or

$$\sigma_1 = 1.125\ E\ \epsilon_1 \pm 0.375\ E\ \epsilon_1 \text{ (for } \eta = \tfrac{1}{3})$$

Analogous considerations for σ_2 give:

$$\sigma_2 = \frac{\eta}{1-\eta^2} E \epsilon_1 \pm \frac{1}{1-\eta^2} E \epsilon_1$$

or

$$\sigma_2 = 0.375\ E\ \epsilon_1 \pm 1.125\ E\ \epsilon_1 \text{ (for } \eta = \tfrac{1}{3})$$

Observation of Table II shows that the maximum possible error would be larger if the uni-dimensional stress formulas were used. For σ_1: $\pm$ 0.5 $E\epsilon_1$, and for σ_2: $\pm$ 1.5 $E\epsilon_1$.

The same reasoning applies to Table III in respect to zone 5. Similar results are obtained. In Table I, these final results are introduced for zones 2 and 5.

Therefore, in zones 2 and 5 brittle coatings do not allow stress calculation with scientific accuracy. However, even in zones 2 and 5, the information given by the coating is useful for technical purposes, and the approximate formulas are usually accurate enough. If higher accuracy is desired for points inside the field of these zones, it is always possible to separate both stresses by using analogies based on Laplace's equation, or the iteration method. For this purpose the free boundaries give directly $(\sigma_1 + \sigma_2)$ and the boundary line of zone 4 gives that sum by a simple arithmetic operation. Application will be shown in Fig. 6, appearing in Part II next month.

For points of zones 2 and 5 belonging to free boundaries, the knowledge of one principal strain is enough to calculate the principal stresses. The uni-dimensional stress formulas should then be used.

D. Zone 1

When the coating does not break (zone 1) we still may have some idea of the value of the stresses. The fact that the coating does not break means that the strain in that region is smaller than the sensitivity strain. This information shows us that the two extreme possible combinations of strains are the two isotropic cases, corresponding to singular points, with $\epsilon_1 = \epsilon_2 = \epsilon^d_s$ and with $\epsilon_1 = \epsilon_2 = \epsilon^r_s$.

For isotropic strains the principal stresses are (see Table II):

$$\sigma_1 = \frac{1}{1-\eta} E \epsilon_s$$

$$\sigma_2 = \frac{1}{1-\eta} E \epsilon_s$$

This means that all we can know is that:

$$\frac{1}{1-\eta} E \epsilon^r_s < \sigma_1 < \frac{1}{1-\eta} E \epsilon^d_s$$

$$\frac{1}{1-\eta} E \epsilon^r_s < \sigma_2 < \frac{1}{1-\eta} E \epsilon^d_s$$

If the sensitivity of the coating is increased, ϵ_s decreases and the uncracked zone is reduced.

E. Zone 7 and 8

All preceding considerations are based on the assumption that the coating breaks when its strain reaches a limiting value. Experiments show that this assumption is not always correct. Even if $\epsilon_1 > \epsilon^d_s$, when $\sigma_1 \gtrless 0$, the coating does not break. In other words, if the strain is produced by Poisson's effect only, the coating does not break.

That is why existence of zones 7 and 8 should be taken into consideration. Although according to the constant strain law of failure a value of ϵ_2 for zone 8 should be obtained, the fact is that the coating does not break and we have to assume the value of the second strain as zero. Therefore, in zone 7 the same formulas should be used as for zone 5, and in zone 8 the same formulas as for zone 2. However, the error introduced by calculating the principal stresses as a function of one single principal strain in these zones is smaller than that in zones 2 and 5, as can be seen in the column of errors in Table I.

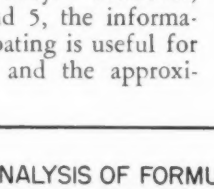
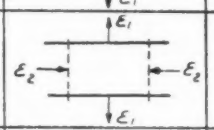
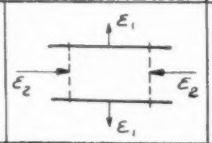
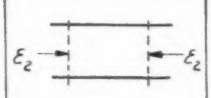
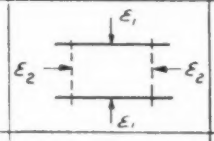
F. Zones 9 and 10

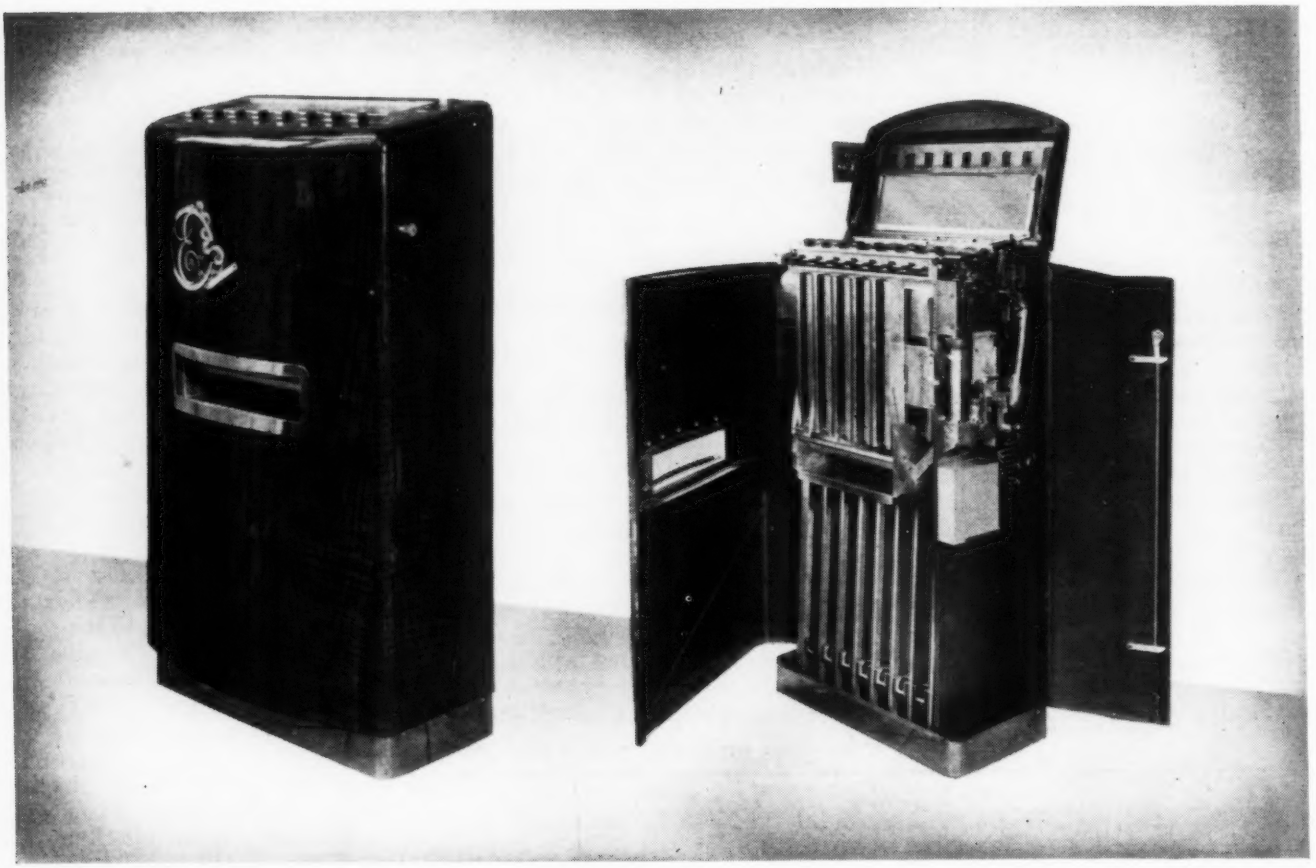
It is possible to obtain isostatics even in those regions where the strain is smaller than the strain sensitivity and in those regions (zones 7 and 8) where the tensile strain is produced only by Poisson's effect. (See Fig. 1 in Part I and Fig. 2 in Part II) This is done with the refrigerating technique. The author's discussion of this technique appears on p. 20 *Proceedings*, 15th Photoelasticity Conference, June 1942.

Rows 9 and 10 of Table I show that the refrigerating technique does not change the isostatic pattern. The isoentatic pattern, however, could not be determined as long as the variation of strain as function of temperature and time is not known. But the information obtained (direction of the principal stresses) is important, and facilitates the placing of strain gages so as to reduce their number to one or two.

Part II will appear in the July issue.

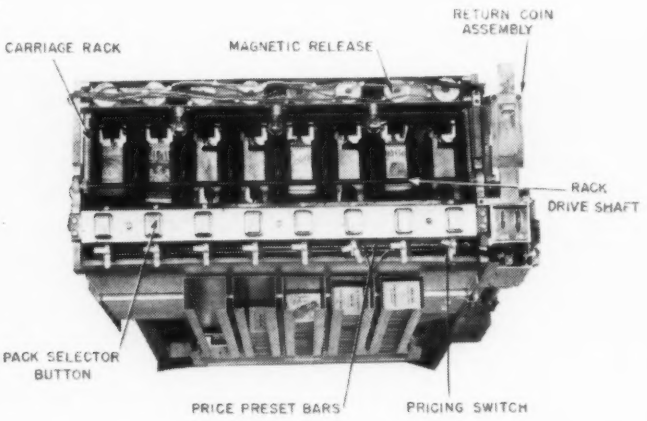
TABLE III—ANALYSIS OF FORMULAS USED FOR DETERMINATION OF THE PRINCIPAL STRESSES IN ZONE 5

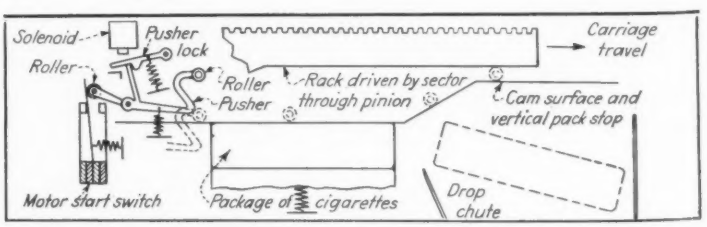
	Combination of Strains	Value of the Stresses in Function of $\mathcal{E}_2$	Formulas when $\eta = \frac{1}{3}$
If $\mathcal{E}_1 > -\mathcal{E}_2$ there would be isostatics obtained by direct load in contradiction to definition of zone 5			
Pure Shear $\mathcal{E}_2 = -\mathcal{E}_1$ (limit case)		$\sigma_2 = -\sigma_1$ $= \frac{1}{1+\eta} E \mathcal{E}_2$	$\sigma_1 = -0.75\ E\ \mathcal{E}_2$ $\sigma_2 = 0.75\ E\ \mathcal{E}_2$
Uni-dimensional Compressive Stress (pure compression) $\mathcal{E}_1 = -\eta\ \mathcal{E}_2$		$\sigma_2 = E\ \mathcal{E}_2$ $\sigma_1 = 0$	$\sigma_2 = E\ \mathcal{E}_2$ $\sigma_1 = 0$
Uni-dimensional Compressive Strain $\mathcal{E}_1 = 0$		$\sigma_2 = \frac{1}{1-\eta^2} E \mathcal{E}_2$ $\sigma_1 = \frac{\eta}{1-\eta^2} E \mathcal{E}_2$	$\sigma_2 = 1.125\ E\ \mathcal{E}_2$ $\sigma_1 = 0.375\ E\ \mathcal{E}_2$
Singular Point $\mathcal{E}_1 = \mathcal{E}_2$ (limit case)		$\sigma_1 = \sigma_2$ $= \frac{1}{1-\eta} E \mathcal{E}_2$	$\sigma_1 = 1.5\ E\ \mathcal{E}_2$ $\sigma_2 = 1.5\ E\ \mathcal{E}_2$
By definition $\mathcal{E}_1$ cannot be smaller than $\mathcal{E}_2$			



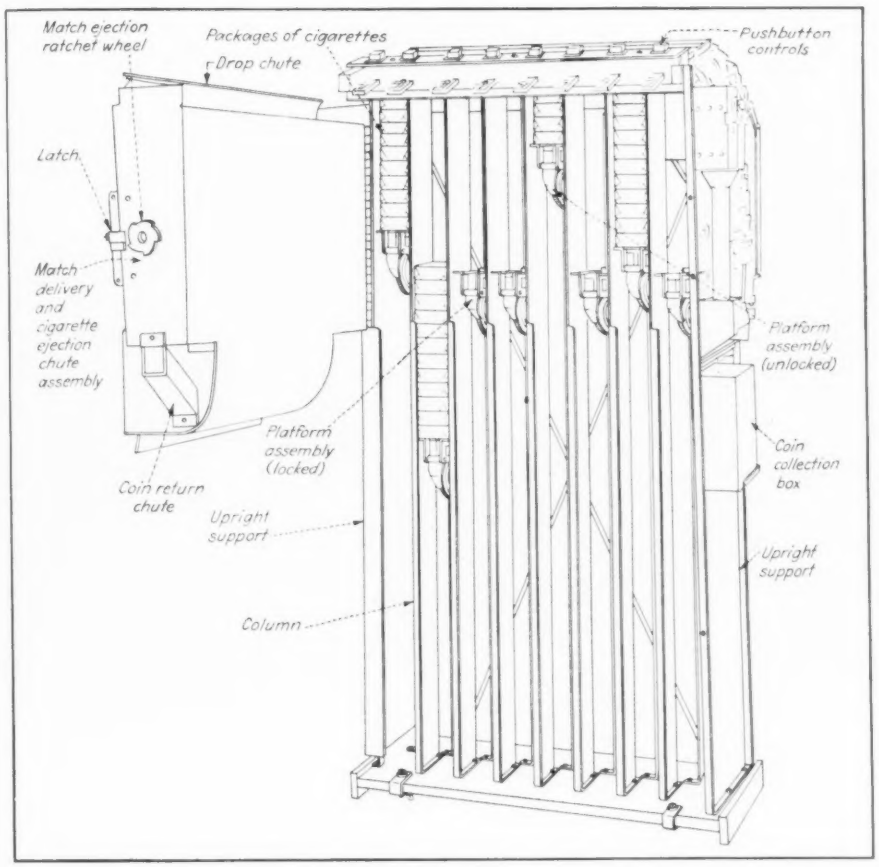
Automatic Electric Cigarette and Match Merchandiser

Designed for simple, troublefree operation, the Electro cigarette merchandiser includes an electric motor drive. The machine delivers a selected package of cigarettes and a pack of matches by depressing a pushbutton control after depositing the correct amount of change. Made of stamped and die cast parts, the 200 lb machine has a standard A.B.T. slug rejector. Exterior grain finish of the 4 ft high merchandiser is baked-on mahogany, light oak or walnut lacquer. The mechanism is inclosed in a hinged stamped steel cabinet that is provided with a lock. Cost of current to deliver the 320 packs of cigarettes is 2¾ cents. The machine is made by the C-Eight Laboratories, New Bedford, Mass.





RACK CARRIAGE DETAILS show how an individual pusher is tripped by the solenoid, thus closing motor start switch and moving carriage to eject pack. Rollers on pusher rise up on cam surface and relock pusher assembly as pack falls in chute.

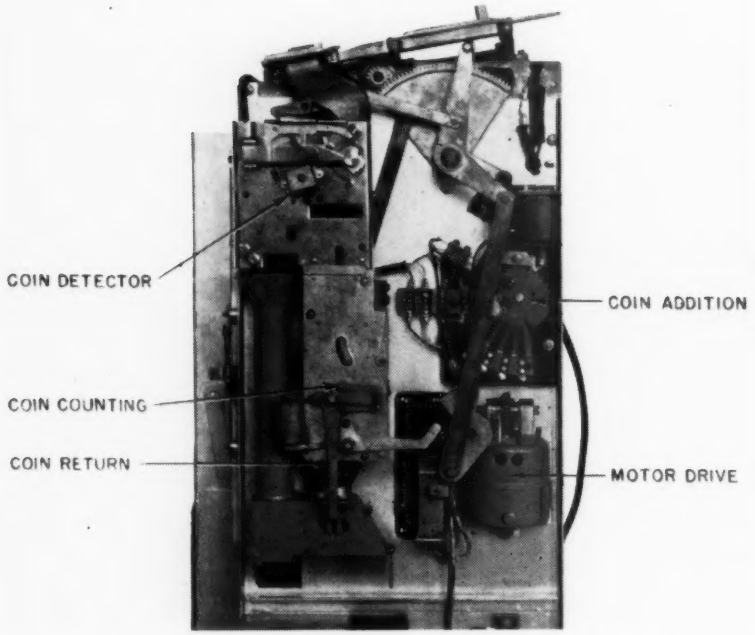


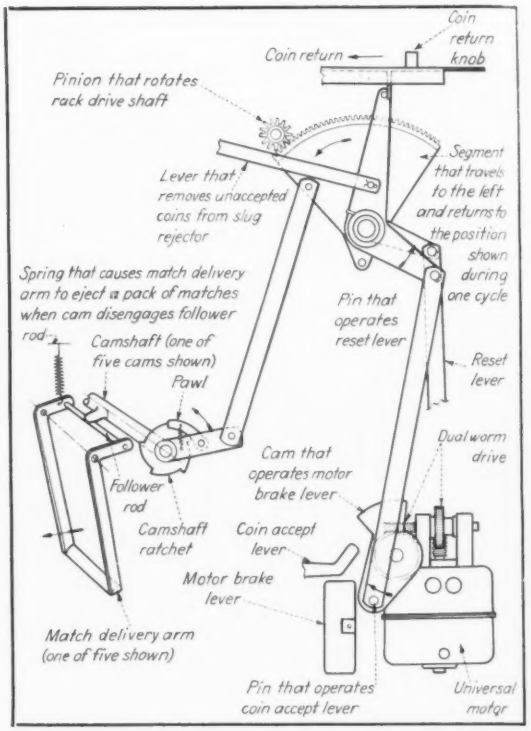
MACHINE OPERATION

COINS DEPOSITED in the machine energize a coin counting mechanism that moves contacts to positions corresponding to 15, 20 or 25 cent sales. These positions are made to correspond to the button controls by setting the price preset bars. If the proper amount of money is deposited, depressing a pushbutton will cause a solenoid to trip the pusher assembly and energize the motor. The motor, through a system of gears and links, advances the carriage, thereby pushing out a package of cigarettes and a package of matches into the well at the front of the machine and deposits the coins in the coin box. When the carriage returns to its original position, the motor stops and the cycle is completed. If an incorrect amount of change is inserted, or counterfeit money is used, the coin return lever is pulled and the money is directed into the well at the front of the machine. The coin counter is reset either when the coin return lever is pulled or during the machine cycle. To avoid overload and damage to operating parts, a switch that allows a 10 amp load for 10 sec and then drops to a 0.7 amp load is included in the motor circuit.

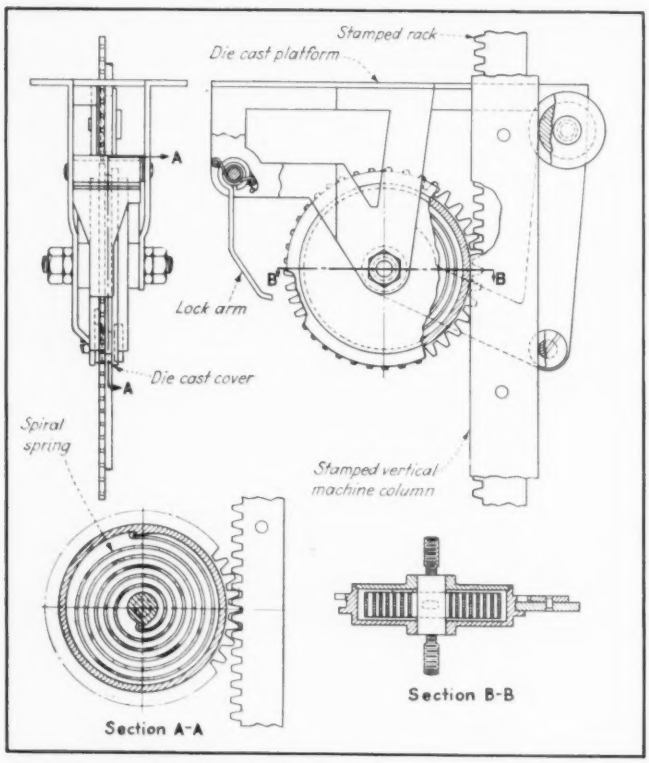
ZINC ALLOY DIE CASTINGS are used throughout the machine. These 31 separate components were specified as die castings to assure the accuracy required in the design. Slot guides in counting unit could be laminated stampings, but here die castings were selected for more accuracy. An added advantage of die cast parts in this application was the ease by which a decorative finish such as chromium plate could be inexpensively applied to the external parts.

Cigarette Machine (continued)

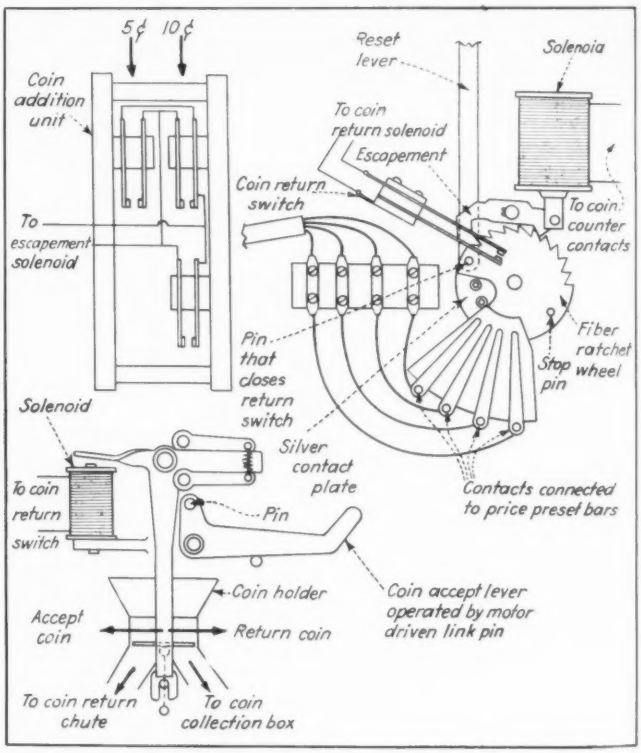



Coin return knob
Coin return
Pinion that rotates rack drive shaft
Segment that travels to the left and returns to the position shown during one cycle
Lever that removes unaccepted coins from slug rejector
Spring that causes match delivery arm to eject a pack of matches when cam disengages follower rod
Camshaft (one of five cams shown)
Pawl
Pin that operates reset lever
Reset lever
Dual worm drive
Cam that operates motor brake lever
Follower rod
Camshaft ratchet
Coin accept lever
Motor brake lever
Match delivery arm (one of five shown)
Pin that operates coin accept lever
Universal motor

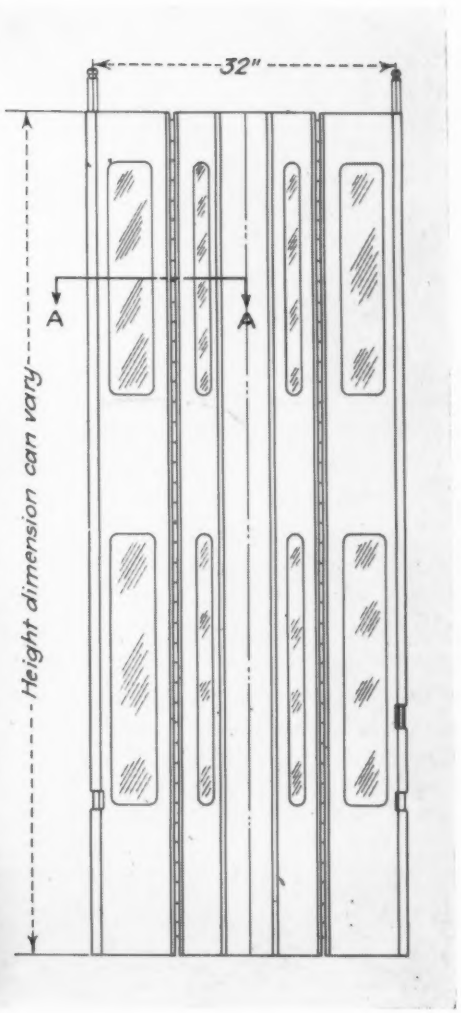
DRIVE COMPONENTS for package and match delivery include a 17,000 rpm universal motor, dual worm gear drive and an assortment of die cast links, levers and toothed parts. A cam, driven by motor, operates a switch that puts a shunt resistance into the motor circuit, thereby braking the motor to 6,000 rpm to avoid overrun at the end of the cycle. Pin and link assemblies include retaining rings to facilitate assembly and repair.



PACKAGE FEEDER is actuated by a spiral spring that is rewound when the feeder is depressed to refill the machine. Stamped rack spotwelded to vertical column engages die cast gear on the feeder. A stop is provided to facilitate filling.

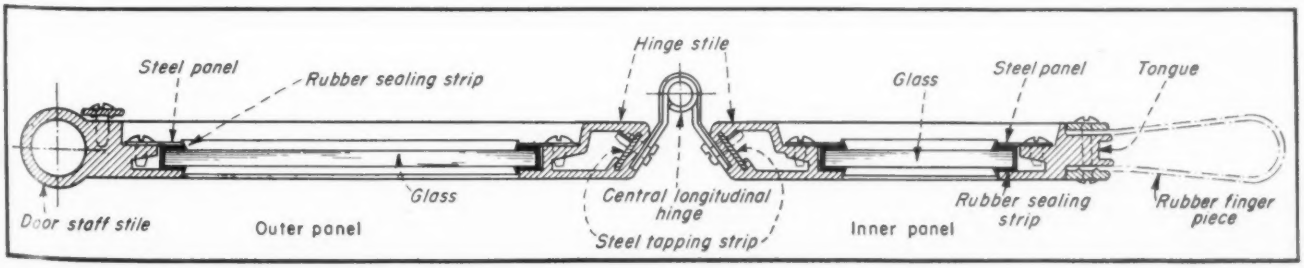


COIN COUNTER is a solenoid-operated escapement. Solenoid is energized by coins hitting whisker switches in the adding unit. Counter is reset during coin return or cigarette delivery operating functions.



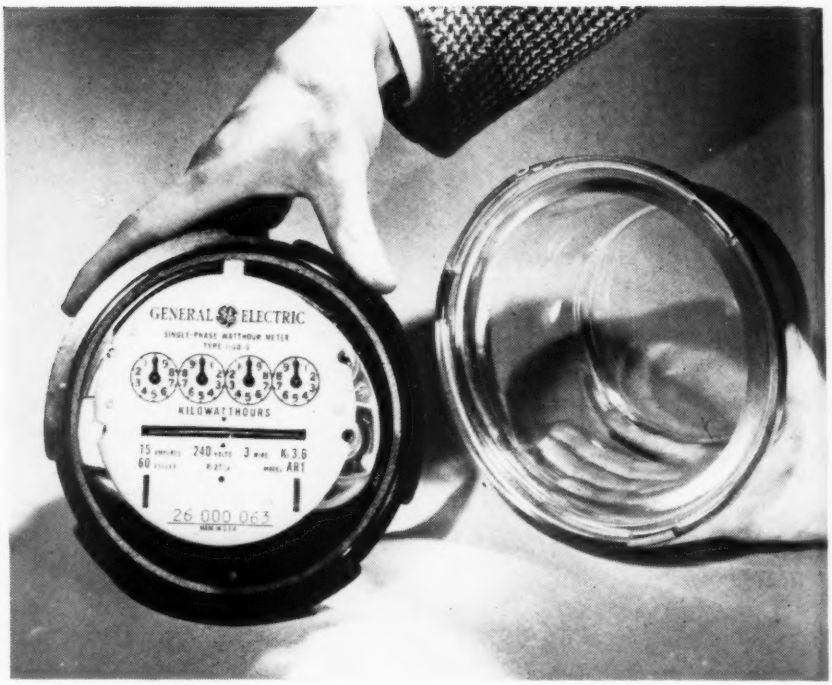
Extruded Aluminum Doors

By combining extruded aluminum sections and steel strips in these bus doors, the use of sound deadening materials was avoided. A smooth exterior that is weatherproof adds to the lightweight feature. Made by the Heintz Mfg. Co., Philadelphia, Pa. for the Mack Manufacturing Company, these patented doors represent a departure from the usual wood and steel construction. Section A-A, through a folding panel, is shown below. Each panel is an integral extrusion comprising an outer stile, a hollow-sectioned hinge stile, and a intermediate panel section. The hinge stile is a rectangular section with a beveled hinge wall. Inner surface of the wall is provided with grooves for the application of steel reinforcing strips, which are used as tapping strips for the hinge screws. The tubular stile of the panel is designed to receive steel shafts at the top and bottom of the panel door. Operating mechanism is attached to the bottom shaft. Extruded panel is blanked out for the window openings. Window glass is applied with a rubber sealing channel. The glass is retained in the extruded aluminum panels with pressed steel panels that act as the glass retainer and the inside lining of the doors.

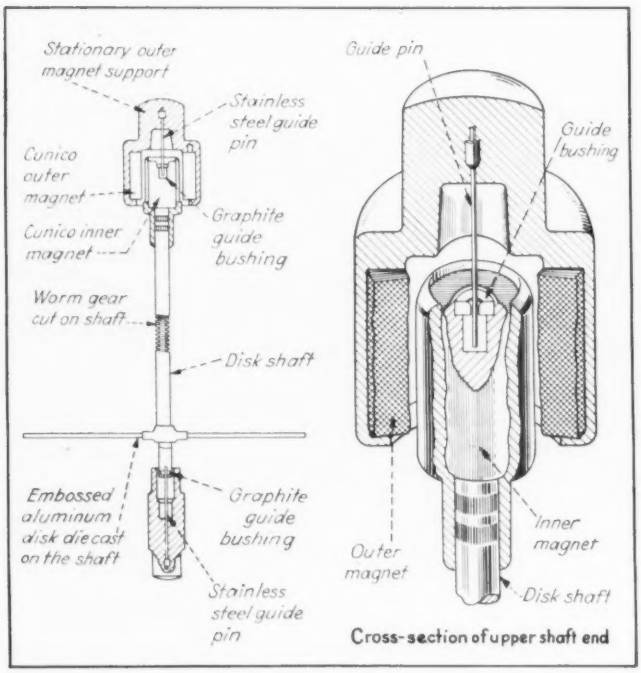


Vertical Shaft Suspended Magnetically

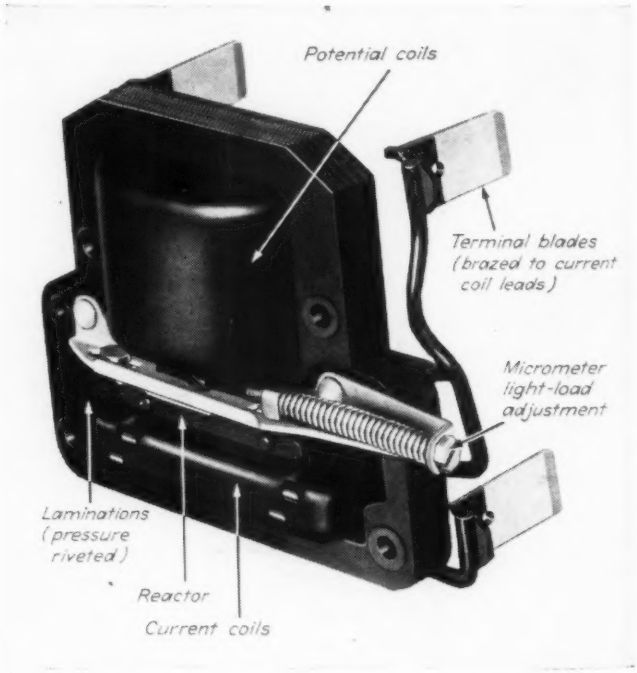
Bearing maintenance problems are avoided in the General Electric type I-50 watthour meter by using a magnetically supported moving element. Corrosion resistant materials and improved insulation design are other features that reduce maintenance cost. Side thrust problems accompanying a magnetic suspension have been solved by providing a unique type of damping system. The meter is made by the General Electric Co., Schenectady, N. Y.



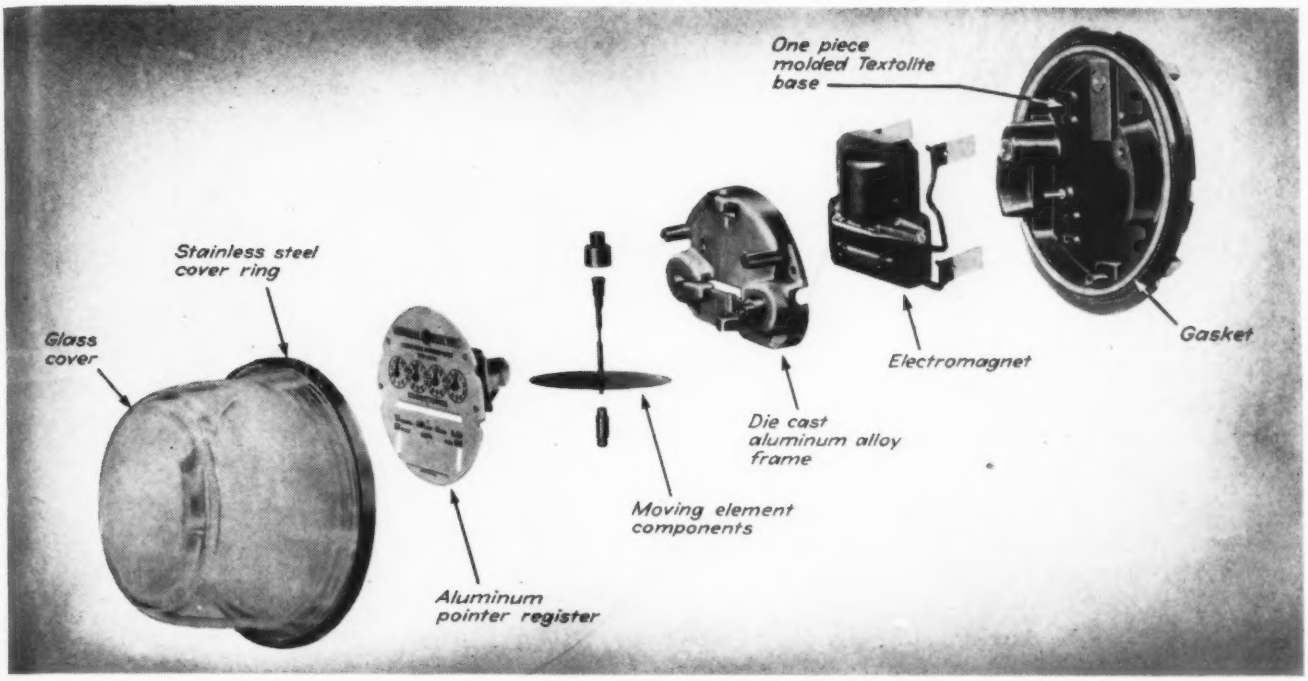
SOCKET-CONNECTED WATTHOUR METER with a pointer register. Unit construction is used throughout the design. Pointer drive includes a conventional dual worm reduction and spur gearing. Drive components are supported by stainless steel pins running in aluminum bearings. A filtered breathing hole is provided in the base of the meter. A gasket, mounted in the textolite base, is the seal for the glass cover.



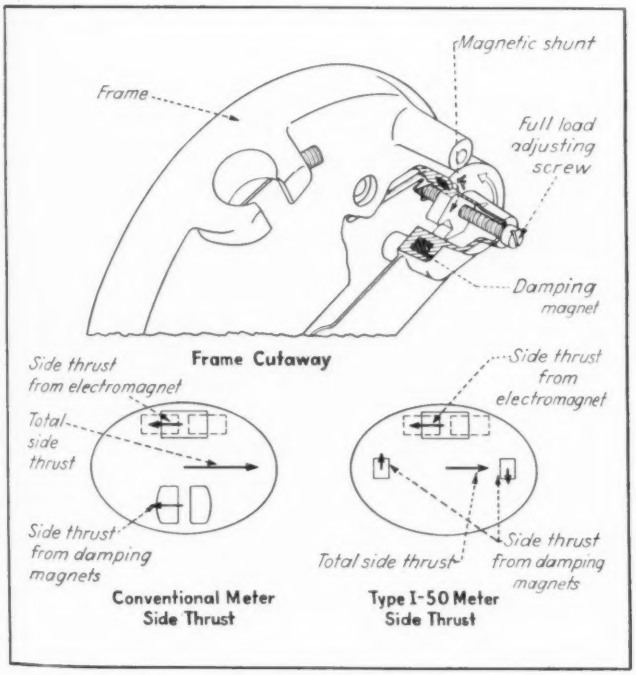
MAGNETIC SUSPENSION for the moving element is located at the upper end of the disk shaft. It consists of two concentric magnets, one mounted on the end of the shaft and the other in a stationary bushing. Magnet material is Cunico, a high coercive, machinable material. The magnets are magnetized axially with opposite polarities. The resulting magnetic field supports the rotating system with a fixed small downward displacement.



ELECTROMAGNET current and potential coils are of molded construction. Formed copper wire current coils are aligned with the electromagnet core in a mold into which butyl rubber is injected and cured. Potential coils are of similar construction except that the molding material is a polyethelene plastic of high dielectric strength and low moisture absorption. Light load and lag adjustments are separate. Class 2 temperature compensation is provided.



EXPLODED VIEW of the type I-50 socket-connected meter. Selection of materials for the component parts was based on their corrosion resistance. Included in the base are ground stainless steel straps that contact the socket when the meter is installed. These straps are mounted on the base with rivets that project into the interior of the meter with a controlled air gap spacing to the line leads of the current coils. Voltage breakdown level of the relief gaps is lower than the insulation level of the electromagnet. Thus, overvoltage breakdown is directed where it does the least damage. Bottom connected type meter has a die cast aluminum base.

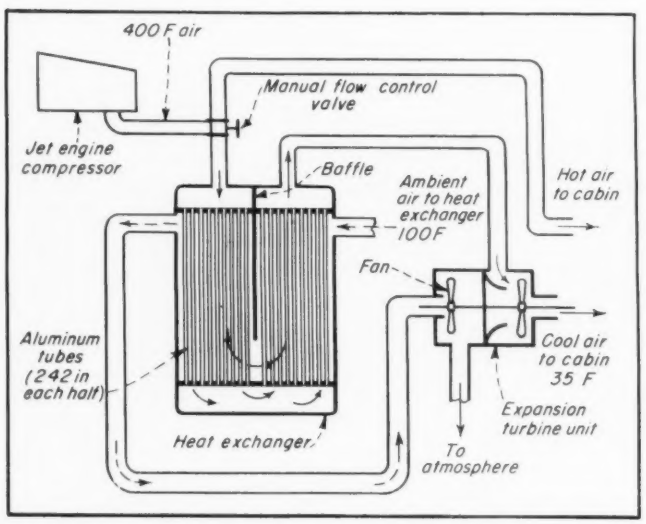


DAMPING SYSTEM consists of two C-shaped Alnico 5 magnets that are embedded as inserts in the die cast aluminum alloy frame. A magnetic shunt in the throat of one of the magnets is moved by a screw to provide full load adjustment. Force diagrams show how net side thrust has been reduced in the design of the I-50 meter by locating the damping magnets close to the electromagnet. Thrust pressure in the type I-50 is 100 psi.

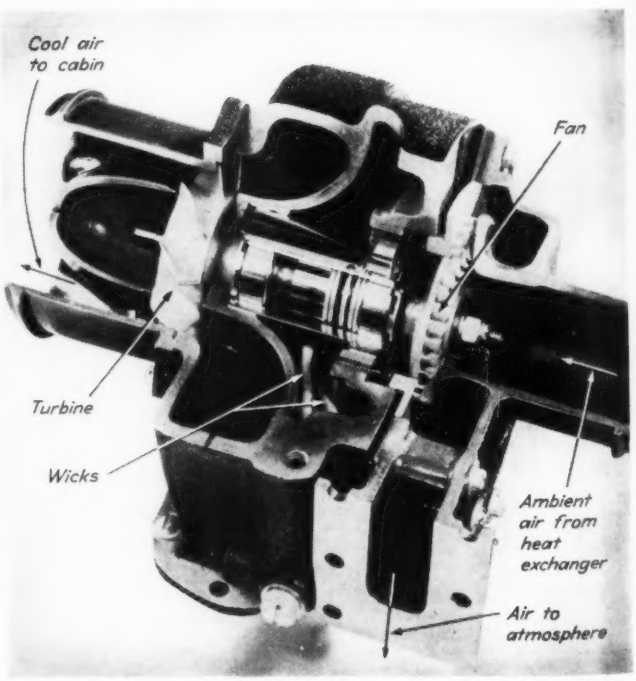
CYCLOMETER REGISTER, which avoids making readings between full digits, can be provided for the type I-50 design. This register has shafts vertically mounted to reduce friction. Two Cunife magnets, one fixed to the bearing plate and the other to the shaft of the first cylinder repel and attract each other during alternating halves of a cylinder revolution. The coercive force of Cunife is sufficient to snap the cylinders into position.

High Speed Turbine Cooling Unit

This expansion turbine unit, designed to control temperatures within pressurized cabins of jet engined aircraft, weighs less than 5 lb. It will create a 135 F temperature drop at 7 lb air flow per min. Developed by AiResearch Mfg. Co., Los Angeles, Cal., it will create a 500 F maximum temperature drop when coupled with an 11½ lb heat exchanger. Operating speed is 100,000 rpm. Maximum speed is 140,000 rpm.



SCHEMATIC DRAWING shows air flow through heat exchanger and expansion turbine unit. Hot pressurized air, (solid arrows), bled from the engine compressor enters a cabin air inlet and passes through the heat exchanger into the turbine. Cooling air from the atmosphere, (dotted arrows), enters exchanger through the ambient air intake and passes through heat exchanger into the fan section of the turbine where it is exhausted through the ambient air outlet. In passing through the nozzles and along blades of turbine wheel, the pressurized air expands and drops in temperature. The load of the fan on the turbine shaft converts further heat in the pressurized air into work and also prevents turbine from overspeeding. Cabin temperature is controlled by regulating the flow valve to obtain a suitable mixture of hot and cool air.

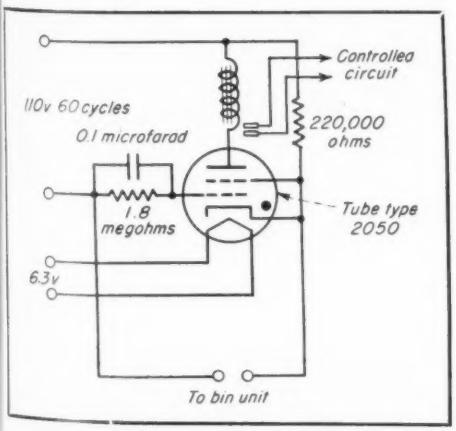


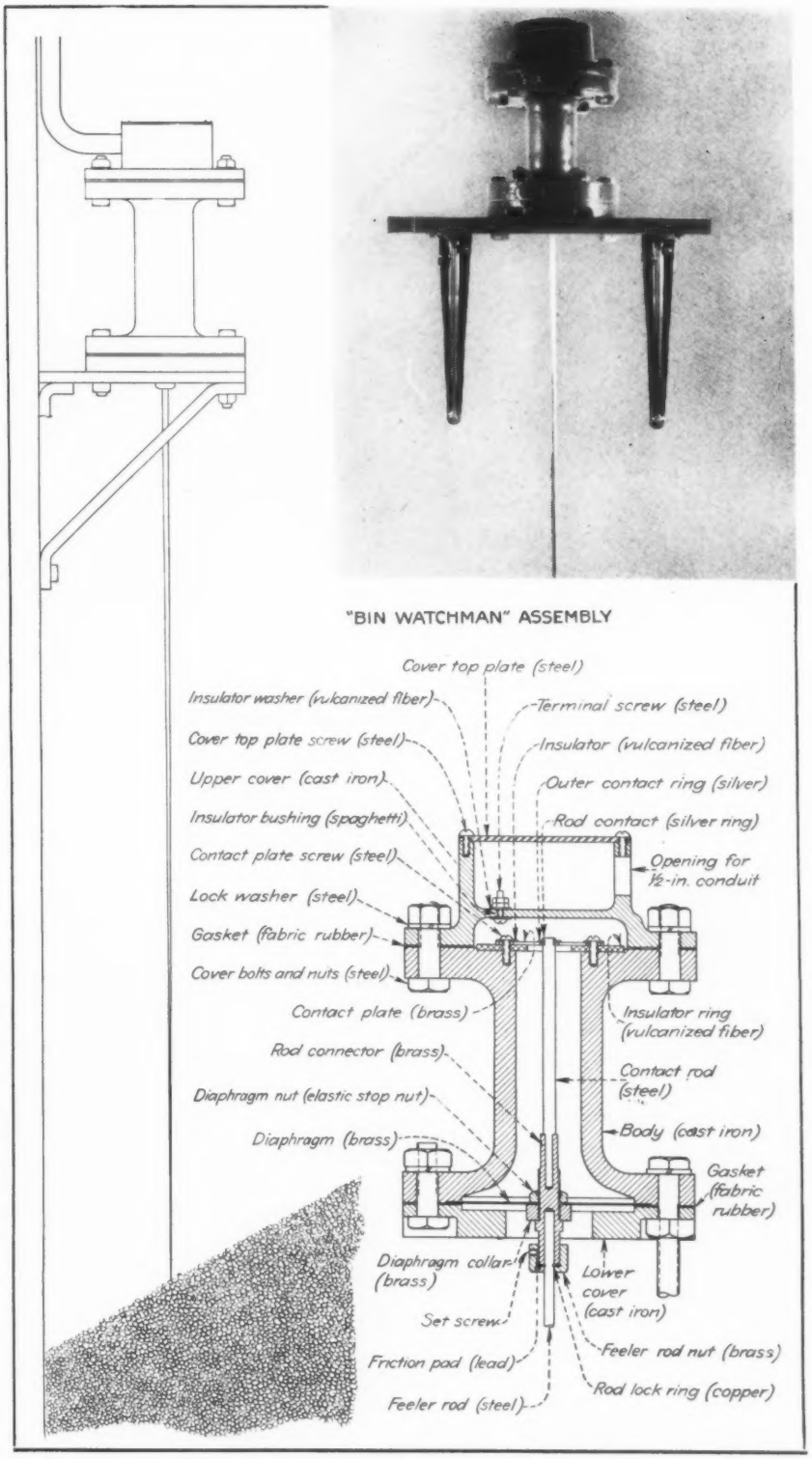
TURBINE CUTAWAY shows the mounting of the one-piece fan and turbine shaft. Lubrication of this assembly is provided by an oil mist circulation system. Oil is conveyed to the shaft through two wicks that extend into an oil sump located at the bottom of the housing. Centrifugal action causes oil to be thrown from shaft is a mist. Two slingers on the shaft circulate the mist through the bearings. Plugs are provided in housing for filling and draining oil reservoir. Flange mountings are provided for the duct work.

Electronic Bin Level Indicator

Designed to indicate and control level in bins being filled with materials such as coal, limestone, grain or other non-fluid materials, this unit has contacts that close when the material deflects a tapered steel rod connected to a brass diaphragm. The unit described here was built for coal mine operation and actuates a mechanism that shifts the flow of coal from one bunker to another as they are filled. To avoid gas or dust explosions the unit is hermetically sealed. The unit can be made extremely sensitive and will then indicate depths of fill for lightweight or flexible materials. Known as the Bin Watchman, unit is manufactured by the G. B. Linderman Corp., Washington, D. C.

INDICATOR UNIT is bracket mounted on the side of the bunker with the rod extending below. The unit has two cast iron covers bolted to a cast iron body. Tapered feeler rod is held in place by a nut that bears on a copper lock ring. Electrical contacts are silver to insure good contact with light pressure. The use of a 7½ ft steel rod in conjunction with an electronic time delay circuit prevents the unit from functioning if it is struck by a single falling or displaced object. For this coal bin application a displacement of 1 in. at the end of the rod is required to make the contact.

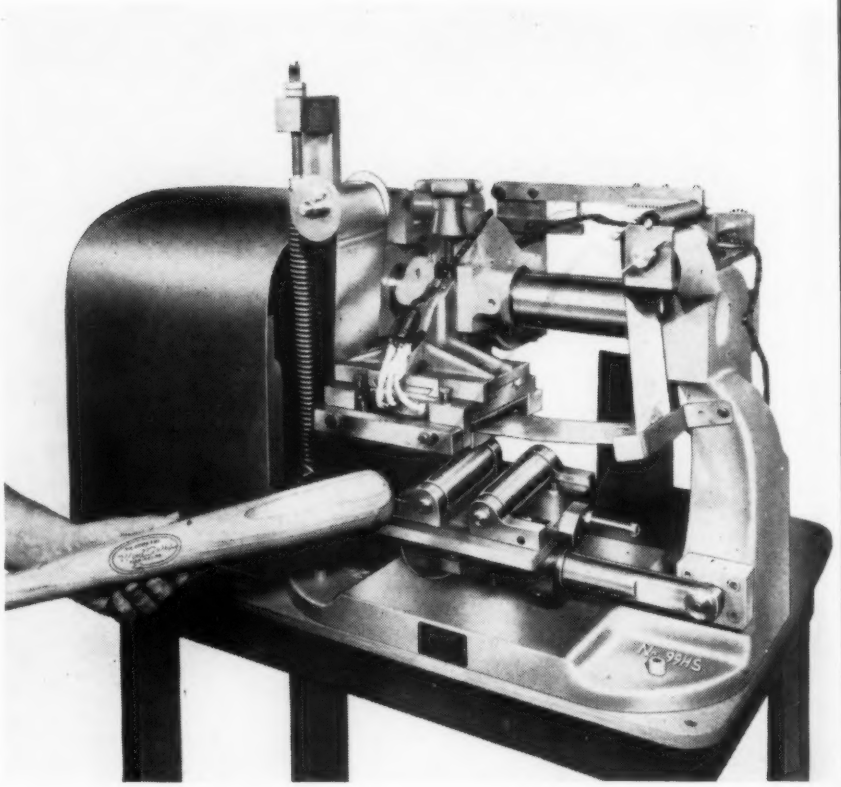


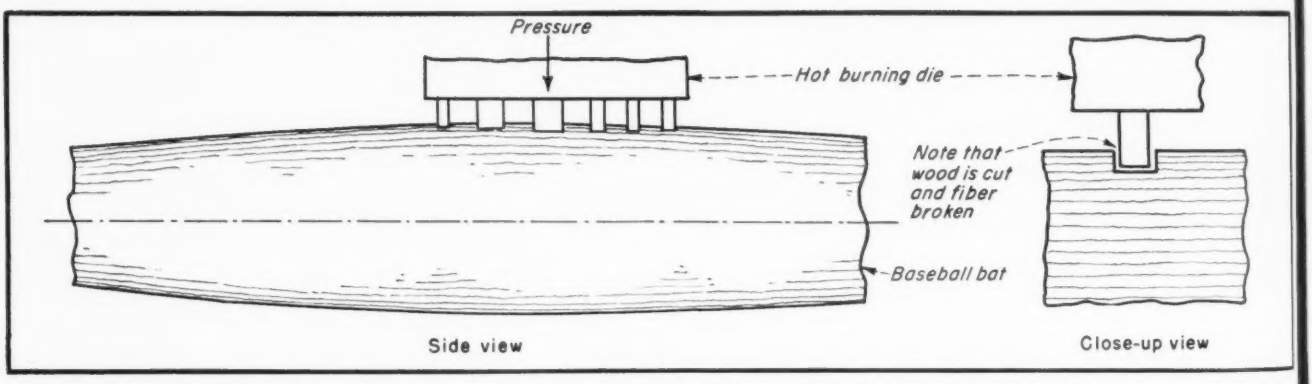


SCHEMATIC DRAWING shows standard time delay circuit that is contained in the relay cabinet. In this cabinet are mounted four separate electronic controls that give a 1 sec time delay to prevent a single blow from operating the conveyor feed controls. The small condenser charges by grid conduction when there is no contact made in the indicating unit. The charge approximately equals the a-c voltage across the tube. When contact is made, the cathode becomes negative with respect to the plate, and the grid negative with respect to the cathode. The thyratron is held from conduction until the charge on the condenser has leaked through the resistor and shunted it. Time delay is controlled by condenser and resistance values.

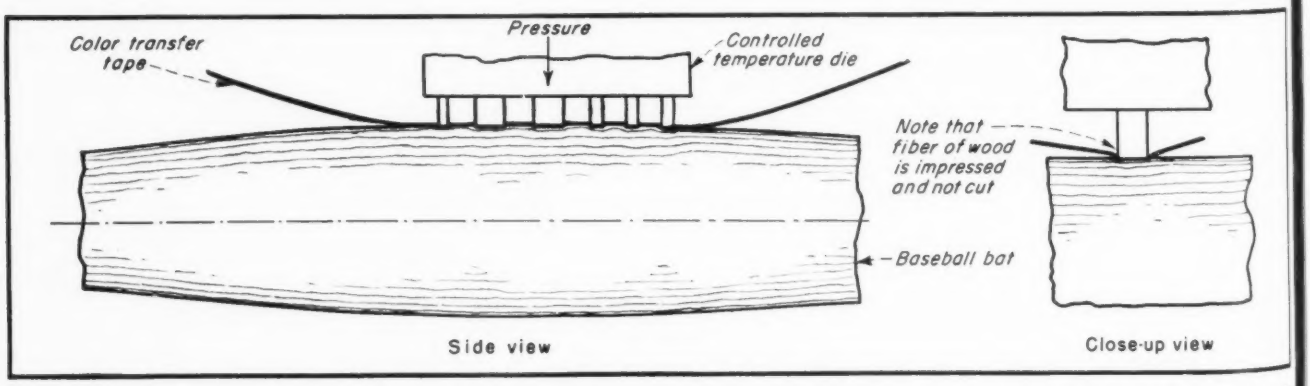
Ball Bat Marker Has Concave Traversing Die

Design problem in this bat marking machine was to place an oval shaped brand on the curved surface of a baseball bat without affecting the physical properties of the bat. The method adopted was that of applying color with controlled heat and pressure. The heat applied is not sufficient to burn the fibre of the wood. The machine is manufactured by the Acromark Co., Elizabeth, N. J.

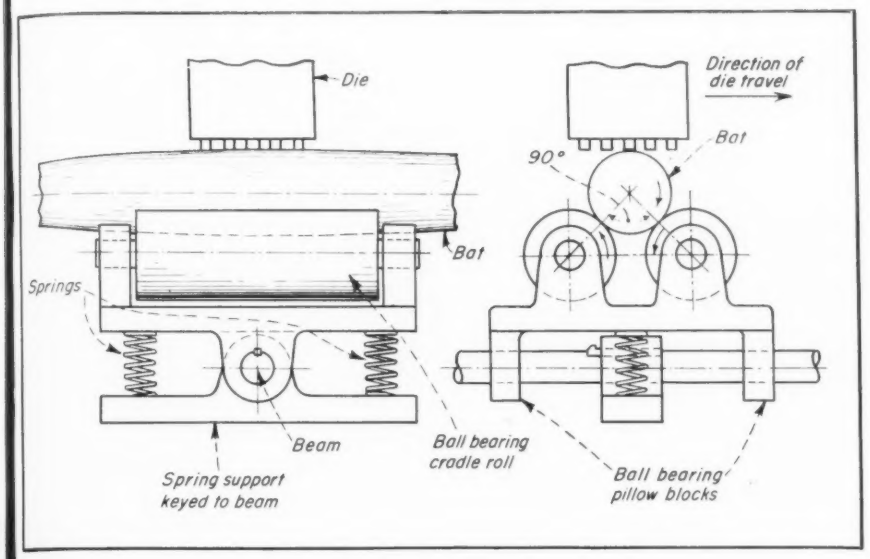




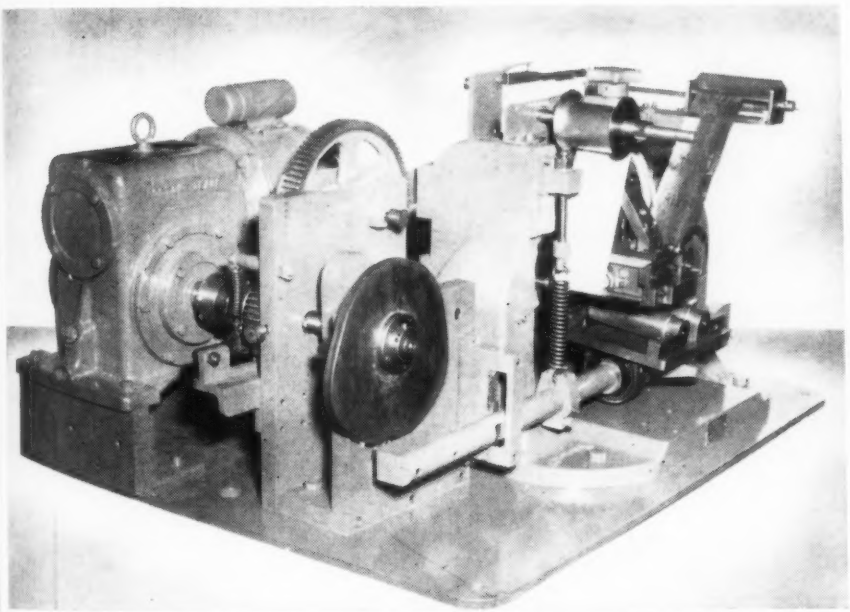
FORMER METHOD used to brand bats was by a flat faced die. This illustration shows how the die has to burn at a greater depth in the middle than at the ends because of the taper, and curvature of the bat. This depth penetration results in a shearing of the fibres that may cause a bat failure. No choice of color was possible with this design.



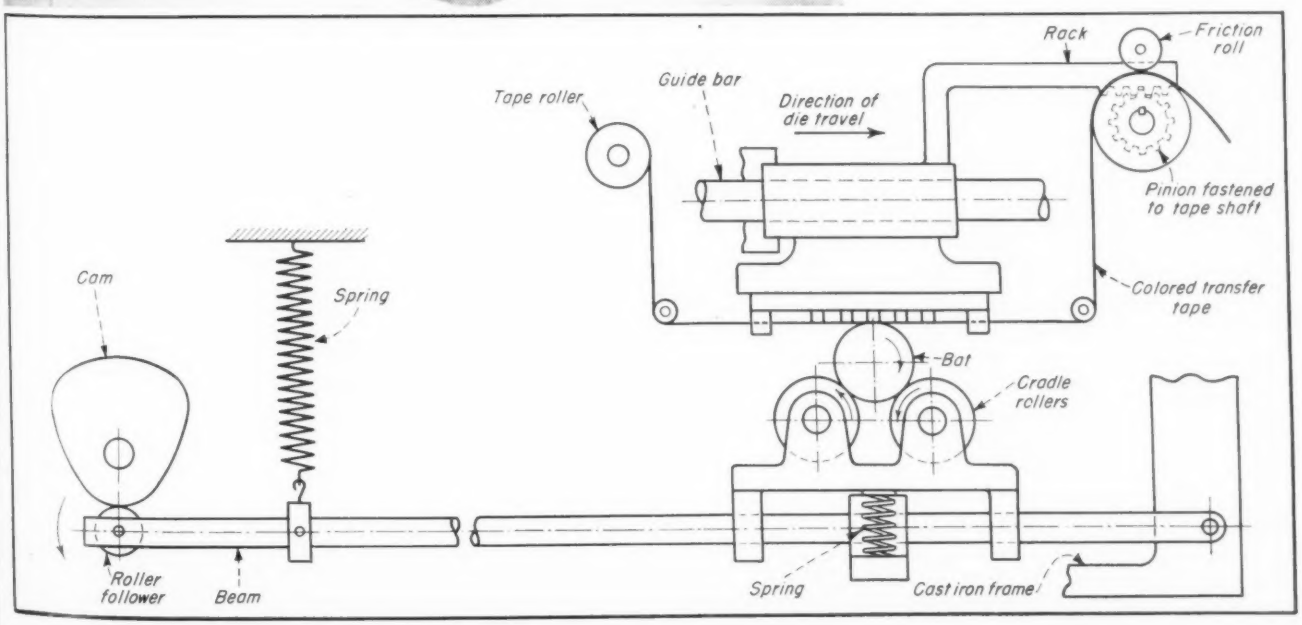
NEW METHOD uses a die with a concave face that approximately conforms to the curved surface of the bat. Color transfer tape is fed between the work and the controlled temperature die. The wood is not cut by this method and an improved appearance of color is given to the trade mark brand. Die surface is curved only in the plane illustrated.



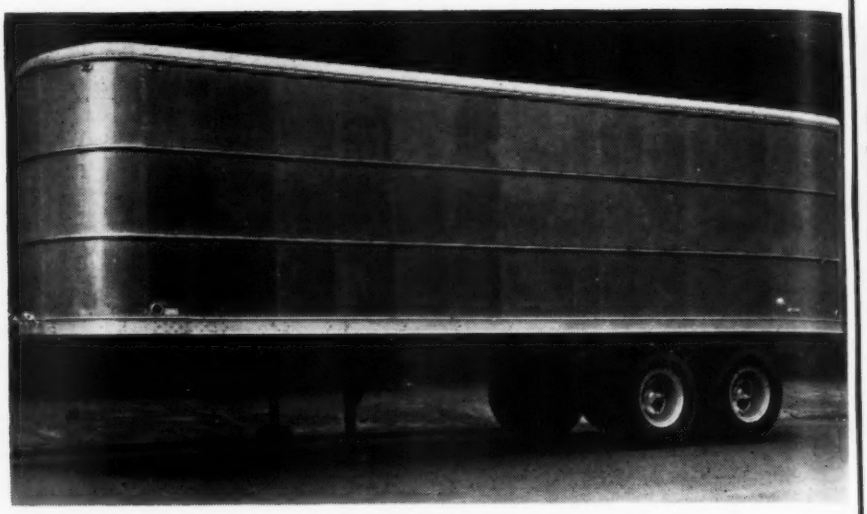
DIAMETER COMPENSATING device is shown. Since the bats are of varying thicknesses and diameters, this mechanism was designed to assure that the branding pressure would be uniform. The ball bearing cradle rolls, upon which the bat rests during the marking operations, are permitted to swivel about an axis normal to the roll centerlines. Springs control this movement and thus insure a uniform branding pressure.



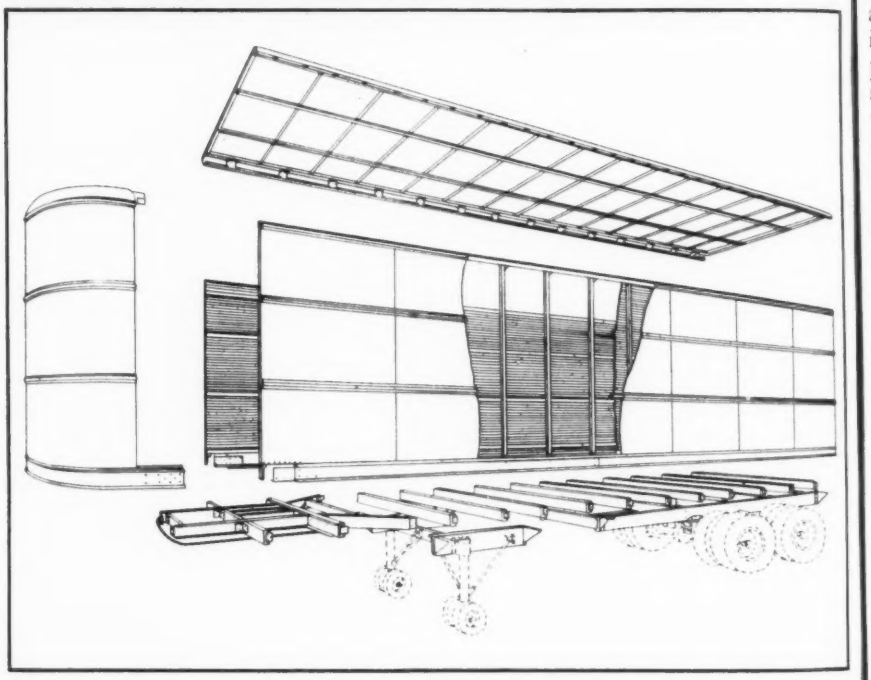
MACHINE DETAILS are illustrated by the photograph and schematic drawing. The beam carrying the floating cradle rolls is controlled by a cam driven by the motor through a worm gear reduction. The die is traversed longitudinally by a crank, driven through a spur gear reduction and automatic pin clutch, in time with the cradle roll cam. The colored tape is fed by a rack on the end of the die that engages an over-running clutch on the end of the tape roll shaft. A stop is provided in back of the roll supports so that an operator will place the bat in the correct longitudinal position.



Trailer Bodies Made from Sub-Assembled Components



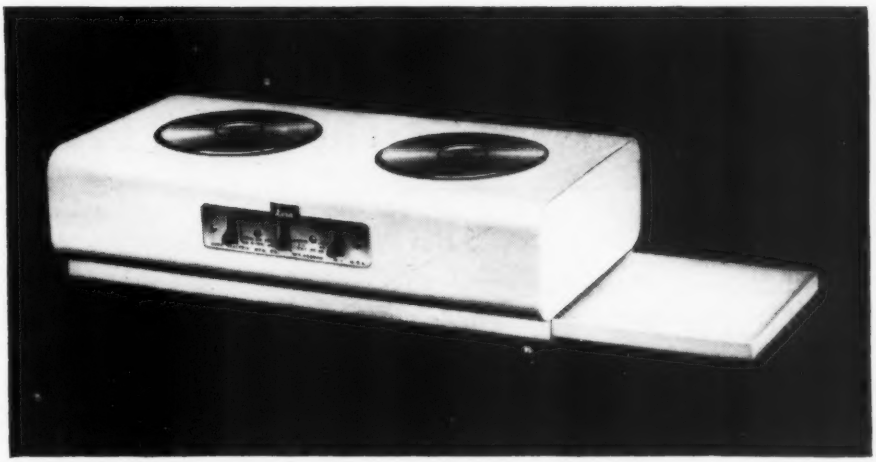
Aluminum alloy truck and trailer bodies made of standard panels and hardware parts give weight savings that increase pay load. When trailers are damaged, the body can be disassembled and standard sections substituted for the damaged parts. By providing standard panel sections in various sizes, parts can be shipped to distributors where they are assembled into custom built units. Such standard aluminum trailer body sections are made by the Reynolds Metals Co., Louisville, Ky. Standard body lengths are from 8 ft, 8 in. to 20 ft, 4 in. in 2 ft increments, with volume contents from 334 cu ft to 1000 cu ft. Standard widths are 7 ft, 7½ ft and 8 ft. Standard heights are 6 and 6½ ft. Dimensions of standard parts are held to the nearest ½ inch.



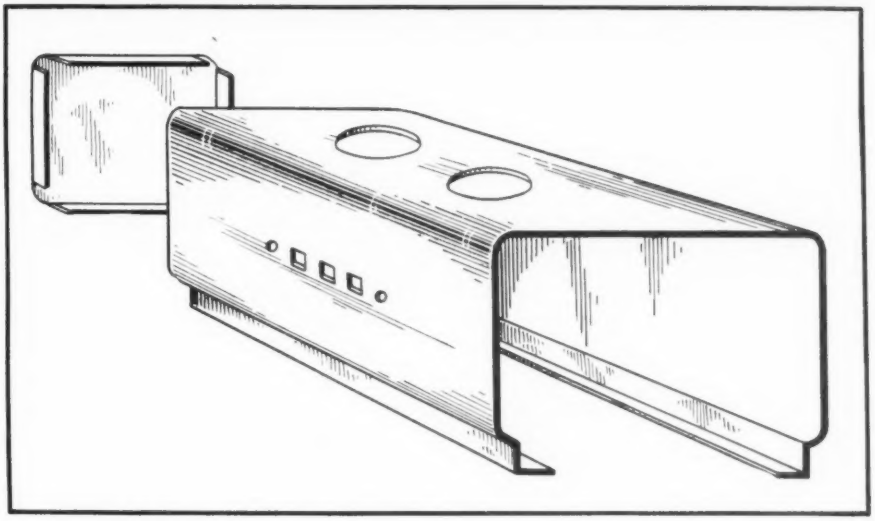
TYPICAL TRAILER BODY and exploded view are shown. Body exterior is flat skin construction that is attached to body stakes with explosive rivets. Top corner casting joins front end section side assembly. Roof is assembled at factory as a unit. Exterior skin acts as load carrying member for each side sub-assembly. Front end section connects to side sub-assembly similar to top corner casting. Parts shown in dotted lines are furnished by the distributor.

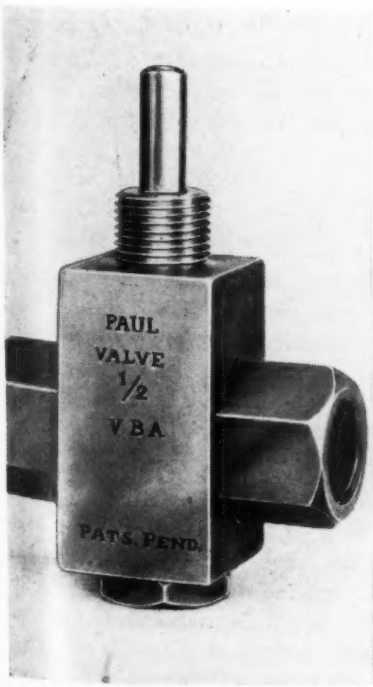
INTERIOR VIEW of truck body shows how side members are strengthened by interior lining of corrugated aluminum sheet. Sidewall stakes are roll formed aluminum sections. Body side rails are aluminum extrusions. Weight comparison of steel and aluminum bodies is shown by a 16 ft aluminum body that weighs 1720 lb compared with a similar steel body weighing 4310 pounds.

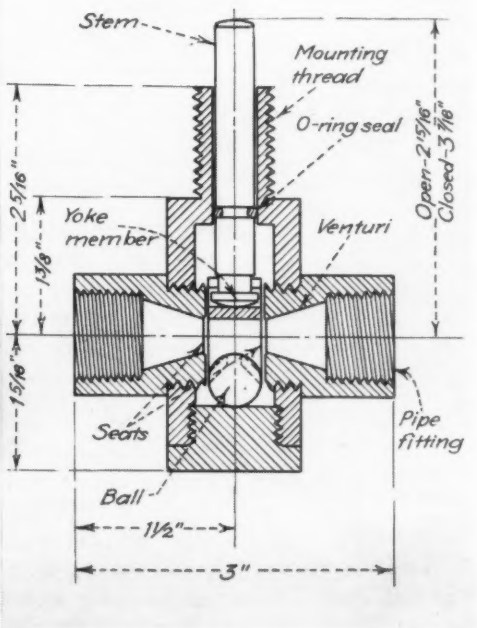
Stove Body Made on Standard Dies



THE BODY, side panels and catch pan on this electric stove are designed to be made on standard bending dies. Only special dies required are those for piercing the heating element holes and notching the side panels. Ventilating slots are stamped under the curved part of the body. Catch pan can be slid out of the stove and emptied of waste that collects under the heating elements. Material is 20 gage cold rolled steel stock. Components are spot welded together. Stove is finished with baked-on porcelain enamel. Standard ceramic and nickrome wire heating elements are covered with a nickel plated stamped cold rolled steel cover. Three double pole, double throw switches provide high, low and medium heats. Stove is made by the Kord Electric Mfg. Co., Mt. Vernon, N. Y. It was designed by Charles Davies Associates, New York, N. Y.







Venturi Ball Valve

HAVING TWO moving parts and no springs, the Paul valve applies Bernoulli's theorem to force a precision ball into the low-pressure center of the stream and into the seat. Valve is opened by pushing on stem, which rolls ball out of seat. Yoke member straddles stream, gives straight-through flow when open. Standard $\frac{1}{2}$ in. size has a $\frac{1}{2}$ in. stroke for full discharge and $\frac{3}{8}$ in. for 80 percent discharge. Force to open valve at 50 psi water pressure is 9 lb. Capacity at full discharge with 20 percent downstream back pressure at 50 psi is 25 gpm. Valve is made for automatic machinery applications by the Paul Valve Co., New York, N. Y.

PROGRESS IN REVIEW

In this running summary of technical developments, space restrictions do not allow giving complete details. Further information relating to any item can be obtained by writing to the Editor of Product Engineering.

PLASTICS AND RUBBER

MASS PRODUCTION OF PLASTIC PRODUCTS, at low cost and high speed, has been made possible by injection molding. Improvements in molding compounds, design of molding equipment and production techniques have made this process a modern answer to single unit fabrication of metal and wood products.

■ A few years ago a four oz injection machine was considered large; early last year 16 oz machines were acclaimed; today 32 oz machines are widely used, 50 oz models are advertised, and moldings up to 10 lb are rumored.

■ A multiple or successive-shot injection method is now in volume production. Plastic material is injected into one mold for the basic part. This cools in a few seconds, and is transferred to a second mold where a shot of a second color or material is injected. This permits production of intricate pieces in two or more colors, without cementing or other expensive fabricating.

■ Productivity of the injection molding machine depends primarily on design of the injection cylinder. In the latest model, the spreader or "torpedo" is heated independently of the cylinder wall; this means higher molding rates, better temperature control, lower pressure loss and easier disassembly and cleaning.

SYMBOLIC OF PLASTICS MATURITY is the continued trend away from applications based only on novelty and eye-appeal, toward the sounder applications based on design for maximum utilization of the inherent properties of plastics. This is emphasized by a recent series of symposia.

■ At the Chicago section meeting of the Society of Plastic Engineers under the panel topic of "Plastics in Product Design," J. A. Boyajian of the Product Manufacturing and Engineering Co. spoke on "Engineering Use of Plastics in Product Design"; L. Morrison Willard, Jr., of the Montgomery Ward Co. spoke on "Plastics in Product Design as Influenced by the Consumer".

■ At the Chicago Rubber Group meeting on the subject "Engineering with Sponge Rubber," and Fred J. Wehmer of Minnesota Mining and Manufacturing Co. spoke on "Engineering with Adhesives."

ENGINEERING possibilities of laminates are receiving wider recognition.

■ Laminated phenolic nipples, ¼ to 6 in dia. and from ¾ in. to several feet long, threaded at both ends, are used for electrical and thermal insulation.

■ Laminated ducts are manufactured by Boeing Aircraft for air conditioning and thermal anticing systems. The Stratocruiser contains 275 of these "thin-as-a-dime" ducts, which will take the impact of a heavy man jumping on them without any damage. The laminates, resin-glass fiber combinations, have replaced metal systems because of 20 percent weight saving, strength, durability and ease of manufacture.

■ Similar polyester-glass fiber laminates are used for the exterior of a modern deluxe house trailer. The lightweight, toughness, non-rusting, non-rotting and the "no-paint needed" feature make this material a natural for this use. The unit is specially treated to make it fireproof.

■ Latest (and best) electrical-grade laminate, also based on glass cloth, is produced by a two-resin treatment. The glass, after a 650 F cleaning process, is coated with a silicone material, dried, and then redipped in a melamine resin syrup and laminated. This treatment provides superior electrical properties even when wet, as well as high arc and fire-resistance.

■ A plastic aircraft wing—low pressure laminated skin with a honeycomb core—looks promising, according to reports from the Royal Aircraft Establishment of England. The latest model utilizes flax, asbestos, and paper as filler materials. Previous work in Germany had produced a complete airplane from paper-base sandwich construction; the plane was successfully flown, but had poor weather resistance.

JUST as it is difficult to define the border-line between plastics and rubber, it is impossible to separate plastics and textiles. Of interest to engineers is the fact that specialized properties can be achieved, broadening textile uses from the "untouchable" women's wear field to all sorts of industrial applications.

■ Polyvinyl chloride, well known as a plastic material, and acrylonitrile, one of the constituents in the oil-resistant synthetic rubber, are combined to produce Vinyon N, an improved textile fiber. Advantages over previous vinyl fibers include greater strength, toughness, chemical resistance, non-flammability, low water absorption and immunity to rot and mildew.

■ Improved air filters have been designed from waste vinylidene chloride monofilaments and scrap metal. The new filters contain curled filaments on the intake side and uncurled filaments on the exhaust side, to provide differential filtering and increased efficiency. Other advantages include flame resistance, color range, and no splinters.

■ Metal seat springs can now be replaced by polyvinyl chloride seat webbing. This application was originally developed for airplane seats and berths because of light weight but the durablity and economy may promote use in other industrial seating. Polyvinylchloride webs are claimed to have slow spring action with complete recovery and no tendency to sag.

ADEQUATE PROTECTION for our infant synthetic rubber industry was written into a bill recently passed by Congress. While gradually reducing government interference, the law provides that government production of synthetic rubber shall be terminated when consistent with national security; the patent pool agreement of December, 1941 is to be disbanded immediately. It is hoped that the latter measure will promote industrial research.

- Rubber producing facilities with a capacity of 650,000 tons per year must be maintained in operating or standing status; at least 220,000 tons must be produced and consumed. The President has been asked to present his recommendation for further legislation on the disposal of unnecessary facilities by January, 1950.

WILL SYNTHETIC RUBBER tires ever be as good as those produced from natural rubber? This controversy has been considerably influenced by the recent development of low temperature-polymerized synthetic rubber, which is promising in road tests.

- The low temperature-produced "Ultipara," Copolymer Corp. product, is reported to be superior to natural rubber in truck and passenger tire treads in all major respects.

- The U. S. Rubber Co. advertise that their product has 29 percent unaged tensile strength, 18 percent aged tensile strength and 53 percent better hot tensile strength and 450 percent better flex life than GR-S stock.

- W. Schulze et al, of the Philips Petroleum Co., have presented in the March *India Rubber World* a complete survey of the physical properties of the new low temperature rubber, Philiprene A, polymerized at 41 F, compared with 122 F for the original war-developed GR-S. Tread wear of Philprene A is claimed to be 20 to 40 percent better than GR-S-10; resistance to cracking and cut-growth is also superior. If reinforced with carbon, this product is reported to be superior in both tread wear and cracking to first quality natural rubber treads.

NONFERROUS METALS

CONTROLLED ATMOSPHERES have been widely used for preserving or improving the appearance of the surface of metals during annealing or heat-treatment. Bright heat-treatment of ferrous metals does not allow many variations, but most nonferrous metals can be annealed to same degree of brightness in different types of furnace and in various atmospheres.

- Copper, nickel and their alloys are oxidized only by free oxygen; they can be protected by use of carbon dioxide or steam. Carbon monoxide, hydrogen and hydrocarbons have also been used successfully.

- Electrolytic copper cannot be handled in hydrogen atmosphere because it absorbs that gas at high temperatures and becomes brittle.

- W. Lehrer, in *Metal Progress,* also points out that hydrogen sulfide present in raw fuel gases can cause undesirable staining of copper base alloys and should be kept at minimum when bright annealing.

- Precious metals are susceptible to oxidation by water vapor at a critical elevated temperature. Because of this, precious metals and their alloys should be bright annealed in highly reducing, by adding hydrogen, atmospheres. . . . Below critical temperature, water-quenching is possible.

- Alloys of brass or gold, containing zinc, require use of inert gas or an actively reducing gas because zinc oxidizes in air, hot carbon dioxide or water vapor.

- Nickel silvers are bright-annealed in reducing atmosphere from which all carbon dioxide has been expelled because at elevated temperatures carbon dioxide combines with hydrogen to produce water vapor—which reacts with zinc.

- Silicon brasses, because of silicon affinity for oxygen, must be annealed in clear dry reducing atmospheres.

- For the light metals, deterioration of the surface by oxidation may be accompanied by blistering. Aluminum and magnesium are unaffected by gases that oxidize copper base alloys, so oxygen and air have been used successfully. Additions of minute amounts of sulphur dioxide are beneficial for magnesium to prevent oxidation or major burning but are bad for aluminum alloys.

WORLD DEMAND for platinum metals has been maintained at a high level, with United States consuming about 200,000 oz platinum and 150,000 oz palladium, according to C. Engelhard, President of Baker & Co., Inc. Wartime work and peacetime research has found many uses for the six platinum metals.

- They are used as catalysts in production of vitamins and hormones.

- A recent paper before the Midland Metallurgical Societies in England, by C. A. H. Jahn, indicates that ruthenium and osmium have never been satisfactorily fabricated; platinum is widely used in the form of wire and contacts; palladium, because of its oxidation at elevated temperatures, must be annealed and cooled in nitrogen; iridium has not been drawn, but, after forging, it has been rolled into sheet, and rhodium has been formed into wire and thin sheet by forging in the early stages.

- Rhodium is more difficult to work than platinum but thin layers can be plated on most base metals. Because it has highest reflectivity of platinum group metals it is being used in forming front surface mirror.

SILICON BRONZES are widely used in chemical processing equipment, heat exchangers, pressure storage chambers and domestic hot water heaters. Attempts to weld these structures have brought out interesting characteristics. These have been summarized by P. J. Gurklis and were submitted in James F. Lincoln Foundation Design-for Progress Award Program.

- Inert gas shielded arc welds, using helium and argon, are sound, strong and ductile. With nitrogen used as shield, the tungsten electrodes were rapidly con-

sumed. Cost of shielded arc welds was no more than that by oxyacetylene techniques.

■ Carbon arc welds made in an atmosphere containing more than 65 grains of moisture per pound of air are usually porous and will not meet bend and tensile test requirements.

■ Shielded metallic arc welding technique made good welds but showed slag inclusions that had to be chipped out.

ELECTRODEPOSITS of any commercially plated metals can now be applied to any commercial magnesium alloy by a new process developed at the Dow Chemical Co. Standard plating techniques are used after depositing a thin zinc film on the parts.

■ Parts so plated have been hammered and rubbed without lifting the deposit, and the finish has withstood heat, humidity and salt spray tests.

■ Decorative qualities of the finish are useful for automotive and building hardware, and cameras.

■ Magnesium engraving plates are being experimentally chrome plated and show increased wear resistance.

NEW MAGNESIUM ALLOYS and new forming techniques have increase use of magnesium and point toward greater use. Three examples are worthy of attention.

■ Douglas-built, Navy D-558-2 Skyrocket used stretch-forming techniques extensively. Preheated magnesium sheet was formed to desired contours by stretching it over a heated die.

■ Process and Development Engineer D. A. Tooley has said that 10 percent of airframe weight can be magnesium alloys now available. If extremely high performance requires unconventional construction, as much as 25 percent can be used.

■ The United States Army, as reported by Lt. Gen. R. A. Wheeler, Chief of Engineers, is redesigning equipment in magnesium so that it can be carried by air. A new alloy has been produced in the laboratory that is twice as strong as present alloys and 12 percent lighter. Making a metallurgical paradox, this stronger alloy is easier to extrude and roll.

IRON AND STEEL

DUCTILE CAST IRON may be on the way if British indications pan out. The British Cast Iron Research Association is investigating possibility of producing iron that will cast with nodular graphite structure and will not require heat-treatment.

■ Ductile castings are now produced by long heat-treatment of white iron castings that changes flaky graphite to nodules.

■ Though properties do not duplicate malleablized white iron yet, deflection of 0.90-1.05 in. and 90 ft-lb impact on 1.2 in. dia arbitration bars indicate toughness.

■ H. Morrogh and W. J. Williams of BCI Research Association have revealed that a silicon iron, low in sulphur and phosphorous, with cerium additions, gives nodular graphite in a cast iron with tensile strength of 65,000 to 70,000 psi, and 145,000 psi transverse rupture strength.

■ Discussing present-day malleable iron, R. Schneidewind and D. J. Reese at American Foundrymen's Association meeting, reported that alloyed malleable with 1 to 1½ percent copper, nickel or molybdenum has about 6,000 psi higher yield strength than unalloyed malleable cast iron.

NEW METHODS of assembling stainless steel have helped push per capita steel output in the United States to seven times above the world average. In 1947, according to the American Iron and Steel Institute, steel sales set peacetime records, though profits per sales dollar were down. Three stainless steel techniques indicate increased future use.

■ Edge welding of irregularly-shaped stainless steel containers by inert gas shielded arc process is facilitated by using templet and magnetic tracing head.

■ Stainless steel tubes have been welded to stainless steel tube sheets, by shielded arc process, to form corrosion resistant condensers. Superficial finish grinding costs $8 as compared to $50 for former welding procedures. Because pure argon shielding gas is expensive, this is not the whole cost story.

■ Furnace brazing of heat-resistant alloys containing chromium, used in construction of jet engines and rockets, has recently been done without oxidation of the chromium. Stainless steel parts, with copper slugs placed at the joints, are sealed in a box that is then filled with pure hydrogen. The sealed box is placed in an electric furnace for 20 min to one hour.

SCUFFING AND SCORING of piston rings, pistons or cylinder walls has been reduced by a protective coating applied to cylinder walls of all engines produced by Dodge Division of the Chrysler Corporation. The manganese iron phosphate crystals give several desirable properties to the coating formed.

■ Coating is porous and traps lubricating oil that insures adequate lubrication at all speeds.

■ Combination of better lubrication and chemical properties of protective coating helps prevent local heating and resultant flow or drag.

■ Crystals become chemically combined with cylinder wall metal and technique could be used to reduce flow of metal under conditions of high heat or pressure.

The "Progress in Review" section, a reader service for 18 months, is now ready to remove its swaddling clothes and take its proper place. Because of the interest shown by readers' inquiries, the editors feel the section should be dressed up in keeping with its functions. Commencing with the July issue, the more mature version will be found under a new title immediately following the table of contents.

Fungicide for Cork

C. D. COOK
ROBERT HARRINGTON
Works Laboratory, General Electric Company

SINCE SIX TYPES of fungi will readily attack untreated cork, experiments have been conducted to determine the desirability of using salicylanilide as a fungicide for cork. To provide a base for estimating desirability, identical tests were run on cork treated with conventional beta naphthol, and on untreated cork samples.

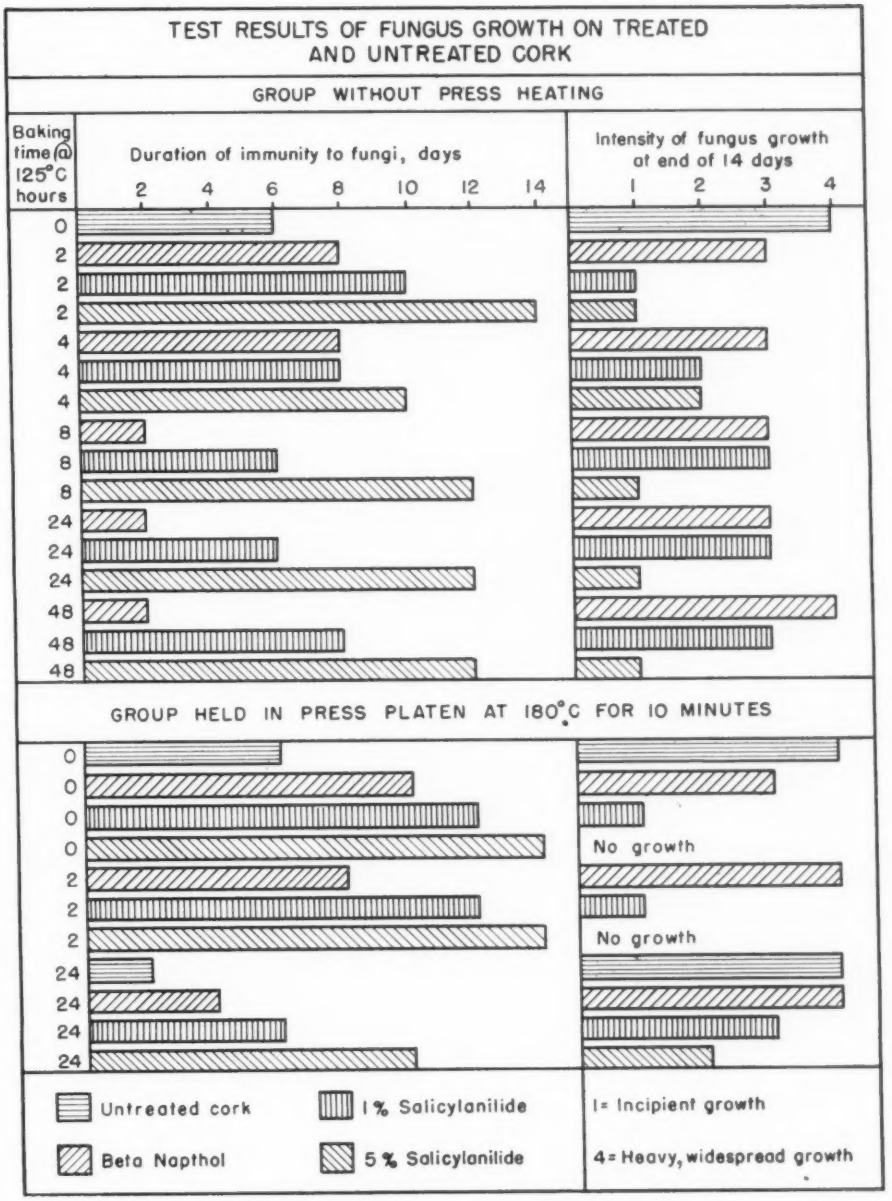
High quality, soft-pressed, phenolic-cemented sheet cork was used for test purposes. Beta naphthol fungicide was applied by roller-coating from a ten percent isopropanol solution. Salicylanilide was applied to the remaining cork samples by dipping in one and five percent solutions of salicylanilide dissolved in equal parts of acetone and naphtha.

Samples of each type of treated and untreated cork were heat-aged at 125 C in a forced convection oven for different periods of time. Since, many cork gaskets are laminated at temperatures as high as 180 C, a number of samples were baked at this temperature between platens of a hydraulic press.

To insure presence of fungi, all samples were innoculated at the end of their baking periods. Spores from six fungi, chaetomium globosum, penicillium sp. aspergillus niger, penicillium lutem, trichoderma sp. and fusarium sp., were used in each inoculation.

After inoculation, the samples were placed in an atmosphere that had a relative humidity of 95 percent and a temperature of 35 C. They were kept in this atmosphere, one conducive to fungi growth, for a period of two weeks, and were inspected for fungi growth each day.

Results of these tests are shown in the accompanying bar graph. Heat aging impairs the fungicidal properties of both materials, but salicylanilide is effected less rapidly and less severely than beta naphthol. An interesting, but unexplained, effect was the reduction in fungus resistance of the plain cork upon baking. This was probably caused by removal of unreacted phenol and other materials in the resinous binder of the cork, which appear to have limited resistance to fungi growth.

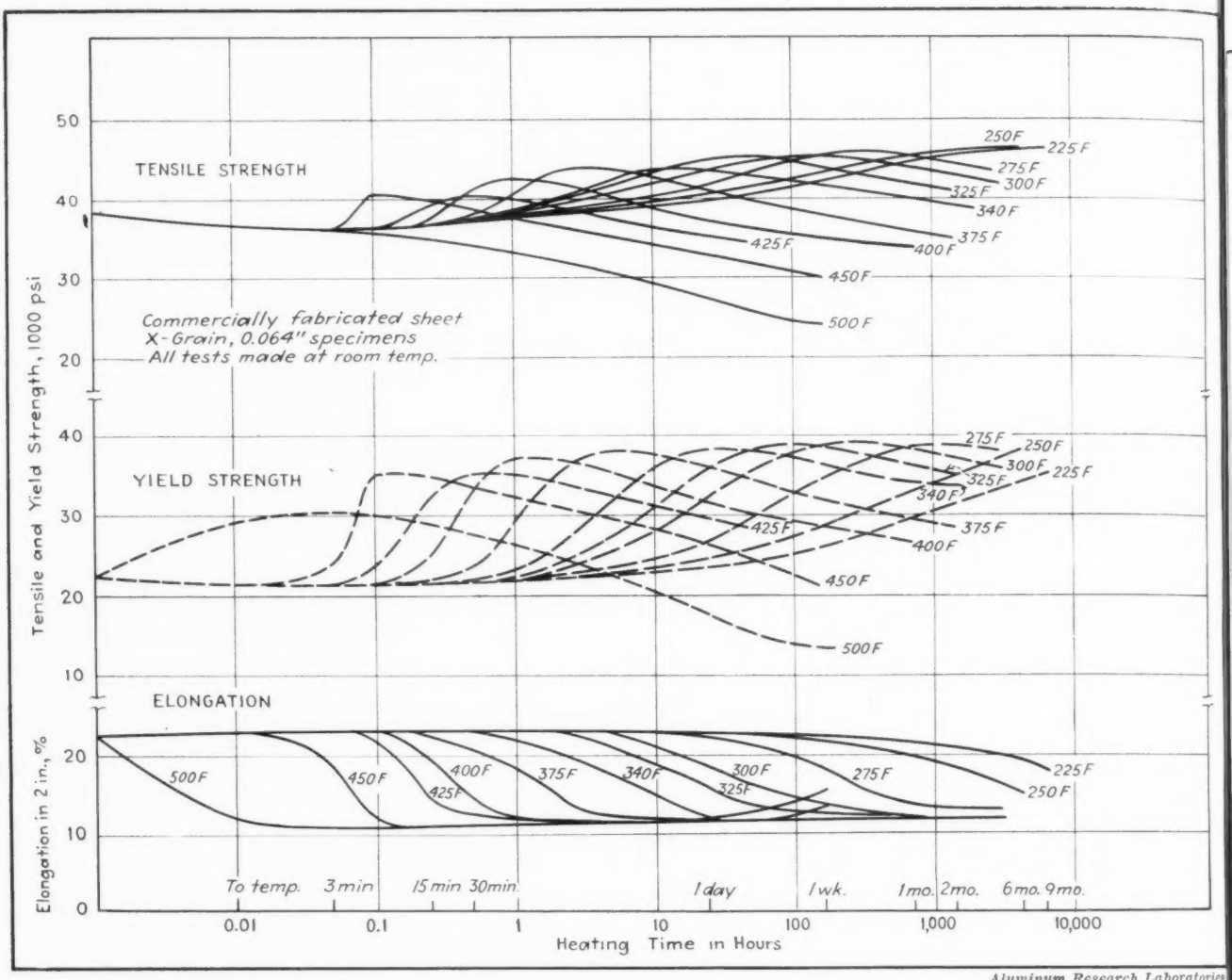

TEST RESULTS OF FUNGUS GROWTH ON TREATED AND UNTREATED CORK
GROUP WITHOUT PRESS HEATING
Baking time @ 125°C hours
Duration of immunity to fungi, days
2 4 6 8 10 12 14
Intensity of fungus growth at end of 14 days
1 2 3 4
0 2 2 2 4 4 4 8 8 8 24 24 24 48 48 48
GROUP HELD IN PRESS PLATEN AT 180°C FOR 10 MINUTES
0 0 0 0 2 2 2 24 24 24 24
No growth
No growth
Untreated cork
Beta Napthol
1% Salicylanilide
5% Salicylanilide
1= Incipient growth
4= Heavy, widespread growth

The tests were extended for an additional two months. Samples of cork treated with five percent salicylanilide, which failed to grow fungi in two weeks, were still unaffected at the conclusion of the longer test. It was noted that in most cases there was a marked tendency for final fungi growth to be independent of the fungicidal properties of the material. Once the fungi appear, they approach the same degree of growth.

When selecting a fungicide for optimum characteristics after heat-aging, choose one that will prevent original fungi appearance for as long as possible.

To determine if any corrosion hazards exist with these materials, samples of beta naphthol and salicylanilide treated cork, salicylanilide crystals, and plain cork were placed in contact with strips of brass, aluminum, silver plated brass, nickel plated brass, galvanized steel and copper. These samples were exposed to the same atmosphere as was used in testing for fungi growth. Except for slight tarnishing of the copper in contact with the salicylanilide treated cork, no corrosion occurred. This confirmed other reports that indicated that salicylanilide is non-corrosive or even corrosion inhibiting.

From the bar graph, it can be seen that short, high heat lowers fungicidal properties of salicylanilide less than long, low heat. With baking temperature of 125 C, it can be seen that heat-aging longer than 4 hr has no effect on either time for first appearance or intensity of fungi growth.



Aluminum Research Laboratories

Fig. 1—Tensile strength, yield strength and percent elongation of 61S-W sheet obtained over a range of time-temperature cycles.

Engineering Characteristics Of 61S Aluminum Alloy Sheet

Fabricating and engineering properties of sheet aluminum-magnesium-silicon alloy 61S. Data included covers heat-treatment; mechanical properties of sheet both without and with heat-treatment, and in work-hardened conditions; and resistance to corrosion. Welding and forming characteristics of the alloy sheet are discussed.

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Development Engineer,
Kimble Division Owens-Illinois Glass Company

AMONG THE WROUGHT ALUMINUM ALLOYS currently being produced in the United States, is the aluminum-magnesium-silicon alloy designated as 61S. In comparison with the higher strength air frame sheet materials, 61S appears to be little known, but it possesses an unique combination of engineering and fabricating characteristics. These should, and are, contributing to the more general use of 61S in sheet metal manufacturing.

In common with the majority of the structural aluminum alloys, 61S is heat-treatable. Its temper modifications can be varied from 16,000 to 50,000 psi in ultimate tensile strength. Unlike the high strength alloys, however, it is easily fabricated by fusion welding. Its formability in the annealed (O) and solution heat-treated (W) tempers is good, and its excellent corrosion resistance and reasonable cost compare favorably with commercially pure aluminum sheet.

Alloy 61S is manufactured in the form of sheets and plates, extruded shapes, tubing, rods and bars. This discussion refers specifically to the sheet stock. The general characteristics are the same for all forms, but detailed fabricating properties differ.

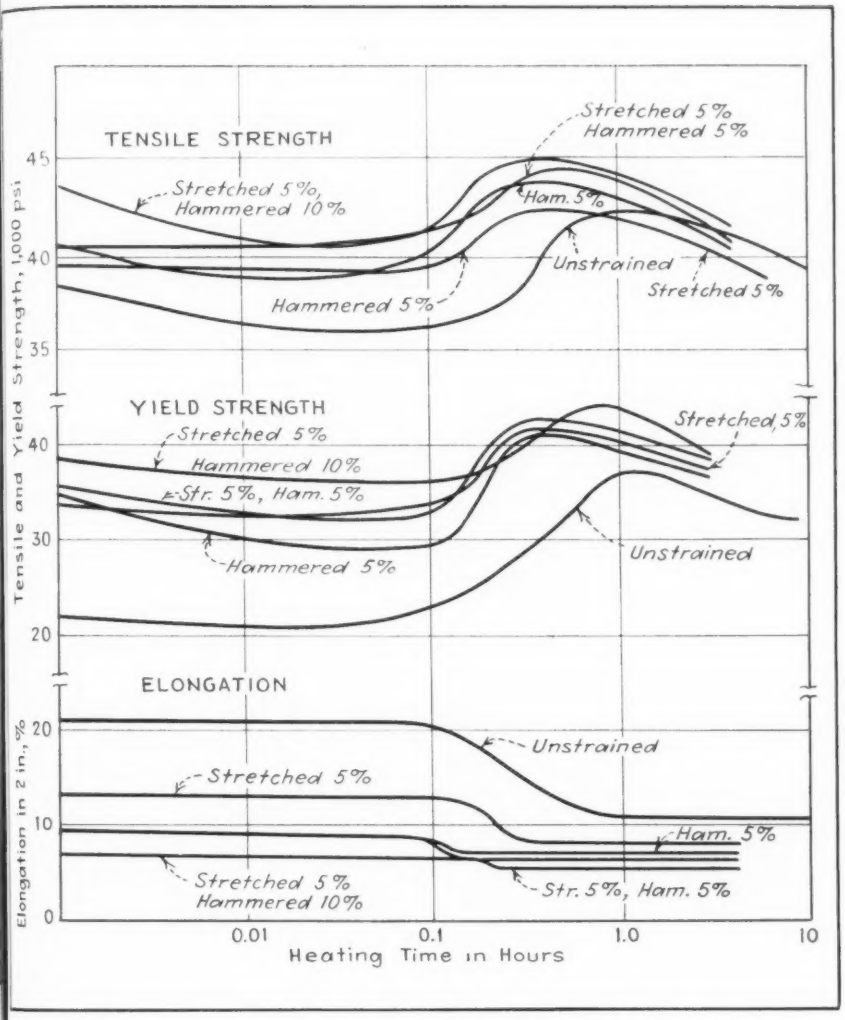


Fig. 2—Effect of exposure at 400 F on work-hardened 61S-W aluminum alloy sheet.

HEAT-TREATMENT. The heat-treatment of the alloy is divided into three parts: Annealing, solution heat-treatment, and precipitation heat-treatment.

Annealing consists of heating to within the range of 750 to 800 F for about two hours, and then cooling to 450 F at a rate not exceeding 50 deg F per hour. Occasionally, it may be desired to soften work-hardened sheet between forming operations. To soften 61S in this condition, it is possible to effect some recovery by heating rapidly to 650 F, holding for about ten minutes, and cooling in air. This practice is not recommended for other than material that was originally in the annealed temper. The author has found that such a short time treatment produces little or no softening of solution-heat-treated sheet, and sometimes develops a less easily formed material.

Solution heat-treatment is a two part operation consisting of an elevated temperature soak and a fairly rapid quench. The temperature range most commonly used is 960 to 980 F. The soaking time for 0.064 in. sheet is 30 minutes. An alternate treatment may be used to stabilize the room temperature mechanical properties of the sheet, in which the solution temperature is within the range of 900 to 930 F. The quenching rate is not critical, so that an air cool may be used with little decrease in resulting strength, which may be of value in heat-treating formed parts for minimum warpage.

Inasmuch as solution heat-treatment produces a thermodynamically unstable condition in this alloy, it is possible to precipitation heat-treat over a wide range of time-temperature cycles. Physical properties of 61S-W sheet obtained with different time-temperature cycles are shown in Fig. 1, prepared by the Aluminum Research Laboratories.

As with the other wrought alloys aged at elevated temperatures, work-hardening prior to the precipitation treatment has a small but measurable influence on the yield and tensile strengths. This is demonstrated in Fig. 2, based on data reported by the author (see "The Precipitation Heat-Treatment of Work-Hardened 61S-W Aluminum Alloy Sheet", *Transactions* A.S.M., Vol. 39, 1947). Furthermore, such work hardening appreciably increases the rate of precipitation. At 350 F, for instance, it is possible to achieve maximum strength in two hours, whereas the usual time required is 8½ hours.

Precipitation heat-treating immediately after quenching in cold water will further increase the strength, as compared to normal processing, but will have no influence on the rate of the reaction. The physical properties given in Table I were obtained through the use of the treatments described.

MECHANICAL PROPERTIES. An overall comparison of the mechanical properties of some aluminum sheet alloys is

Table I—Physical Properties After Thermal Treatment For 0.064 in., 61S Aluminum Alloy Sheet

Treatment	Yield Str, At 0.2% Set, psi	Tens Str, psi	% Elong in 2 in.
Full anneal (780 F 2 hr, cooled to 450 F in 8 hr)	7,000	16,500	24.0
Partial anneal (work-hardened S-W sheet, 650 F 10 min, air cool)*	19,200	27,700	8.5
Solution heat-treatment I (975 F 30 min, cold water quench)	19,800	35,000	20.0
Solution heat-treatment II (925 F 30 min, cold water quench)	15,500	27,500	21.0
Precipitation heat-treatment I (975 F 30 min, cold water quench, held room temp 24 hr, heated 350 F 8½ hr)	41,500	44,600	10.5
Precipitation heat-treatment II 975 F 30 min, cold water quench, immediately heated 350 F 8½ hr)	46,500	50,500	9.5
Precipitation heat-treatment III (925 F 30 min, cold water quench, immediately heated 350 F 8½ hr)	27,500	34,500	11 0

*Properties after work-hardening: Y S, 34,500; T S, 41,000; Elong, 8 percent.

Table II—Mechanical Properties of 0.064 In. Aluminum Alloy Sheet

Alloy	Tensile Yield Str 0.2% Set, psi	Ult Tens Str, psi	Elongation, % in 2 in.	Ult Shear Str, psi	End. Limit, psi
2S-O	5,000	13,000	35.0	9,500	5,000
2S-½H	14,000	17,000	9.0	11,000	7,000
3S-O	6,000	16,000	30.0	11,000	7,000
3S-½H	18,000	21,000	8.0	14,000	9,000
24S-O	11,000	27,000	19.0	18,000	12,000
24S-T	46,000	68,000	19.0	41,000	18,000
24S-RT	57,000	73,000	13.0	42,000	
52S-O	14,000	29,000	25.0	18,000	12,000
52S-½H	29,000	37,000	10.0	21,000	18,000
52S-H	36,000	41,000	7.0	24,000	19,000
61S-O	8,000	18,000	22.0	12,500	9,000
61S-W	21,000	35,000	22.0	24,000	13,500
61S-T	40,000	45,000	12.0	30,000	13,500
75S-O	15,000	33,000	17.0		
75S-T	72,000	82,000	11.0	47,000	22,500
R301-O	10,000	25,000	22.0		
R301-W	41,000	62,000	19.0		
R301-T	60,000	68,000	12.0	43,000	12,500
R303-O*	15,000	30,000	12.0		
R303-T	71,000	77,000	9.0	47,500	22,500

* R303 currently out of production.

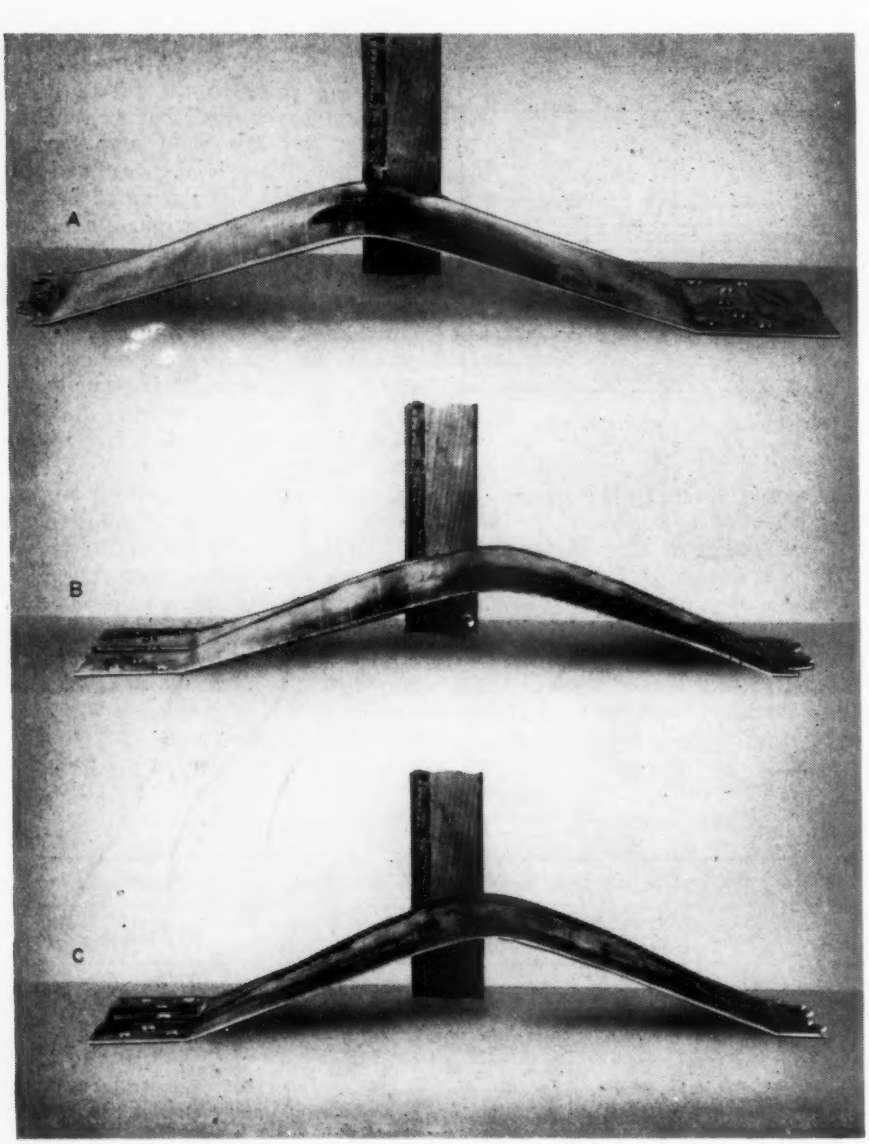


Fig. 3—Specimens after ductility tests. (A) Sheet with no weld. (B) Sheet with machine weld parallel to direction of pull; sheet in as welded condition. (C) Sheet with machine weld parallel to direction of pull; sheet was solution heat-treated.

presented in Table II, which is a compilation of data released by the Aluminum Company of America and the Reynolds Metals Company. The general excellence of 61S is clearly indicated by the typical values in tension, fatigue, and shear.

WELDABILITY. Gas welding operations in 61S are more difficult than in 2S, 3S, or 52S; however, gas welding is practicable and for oxyhydrogen a rate of 4 to 6 in. per min is common. By using oxyacetylene, a speed of 10 in. per min can be attained. Both values are for 0.064 in. sheet. Weld cracking is infrequent; some annealing occurs near the weld region, but the corrosion resistance is not adversely affected as in the higher strength, heat-treatable alloys.

Both bare and covered electrodes may be used to arc weld 61S, but arc welding, except for inert atmosphere welding, is not as satisfactory as gas welding for the thin gages. The arc has too great a tendency to waver even with covered electrodes, and constant care is necessary to obtain high quality welds.

The welding characteristics of the non-heat-treatable alloys and 61S exhibit very little difference when argon-shielded arc welding is used for joining. Using a stabilized a-c machine and a welding current of 90 to 95 amp it is common to machine weld 0.064 in. sheet at the rate of 40 in. per min with an argon consumption of 8 litres per minute. Using downhand welding, a trained operator can weld by hand at the rate of 18 to 20 in. per minute.

Recently the author had occasion to check the formability of argon-arc welded 61S-W sheet. It was found that the loss in ductility is negligible when machine welding is used and the weld is parallel to the direction of the principal straining. Hammering the weld decreases the ductility, while rolling has no such adverse effect. Solution heat-treating after welding produced a ductility greater than that obtainable with unwelded sheet.

The ductility of the welded sheet is indicated in Figs. 3(*A*), (*B*), and (*C*). As shown in Fig. 4, the ends of the test specimens were restrained by bolting them, between two smoothly polished steel plates, against channel irons. As a result, the full strength and ductility is not clearly demonstrated, since tear-out occurred at the bolt holes. When failure occurred in the unrestrained portions of the specimens, it was not preferential to the weld, even though no heat-treatment was performed. In limited tests conducted with 24S-T, R301-W, and

75S-W, it was found that failure originated directly in the center of the weld.

Alloy 61S is readily joined by resistance welding, either with or without cleaning the surface of the sheets to be welded. Consistent welds in excess of AAF or Buaer requirements can be obtained, although tip pick-up is necessarily higher with the uncleaned sheet. In general, when chemical cleaning methods are used, it has been found that alkaline cleaners give the best results.

FORMABILITY. When the solution or precipitation heat-treated material is necessary for strength requirements, it may be desirable to investigate a possible savings in cost. The W temper of 61S hardens when stored at atmospheric temperatures over long periods of time. It is possible, therefore, to purchase at a lower initial cost the as-rolled sheet and to heat-treat it directly before severe forming operations. In this way, advantage can also be taken of the excellent forming quality of the freshly quenched alloy.

For a simple 90 deg bend, it has been found that 61S-O and freshly quenched 61S-W can be formed over a sharp corner. Stored 61S-W sheet requires a radius between $\frac{1}{2}$ and $1\frac{1}{2}$ times the thickness of the sheet. 61S-T requires a forming radius between 1 and 2 times the sheet thickness.

Edge condition may or may not be important, depending upon the application. Sheared 61S with no subsequent smoothing of the edges has a greater tendency than 24S and 52S to produce edge cracks in stretch flanges. For the same reason, it is advisable to deburr 61S prior to stretch forming.

No published data on the tendency of 61S to work-harden are available. Table III presents some results obtained with 61S-W, in which the sheet was held at room temperature for 24 hr after solution heat-treatment. The results indicate that the solution heat-treated temper loses its ductility more rapidly than the non-heat treatable alloys such as 2S, 3S, and 52S. This characteristic is probably true of the annealed temper also, even though it is in the more stable condition.

Where forming applications are severe, or the formation of a high yield strength is desired, it may be valuable to resort to forming at elevated temperatures. Fig. 2 shows, and Dorn agrees, that 61S-W exhibits an increase in yield strength when held in the range of 400 to 450 F for five to twenty minutes. (See, J. E. Dorn, A. E. Flanigan, and L. F. Tedson, "Study of the Forming Properties of Aluminum Alloys at Elevated Temperatures", Part IX, O.S.R.D. Report W-152, Nov. 1, 1944). Dorn further reports (See, Ibid., Part V, O.S.R.D. Report W-111, June 10, 1944), that 61S-T has better drawability at 400 F than does 61S-O at room temperature. 61S-T, however, will exhibit a loss in yield strength when held in the range of 400 to 450 F for periods exceeding five minutes near the upper limit of temperature.

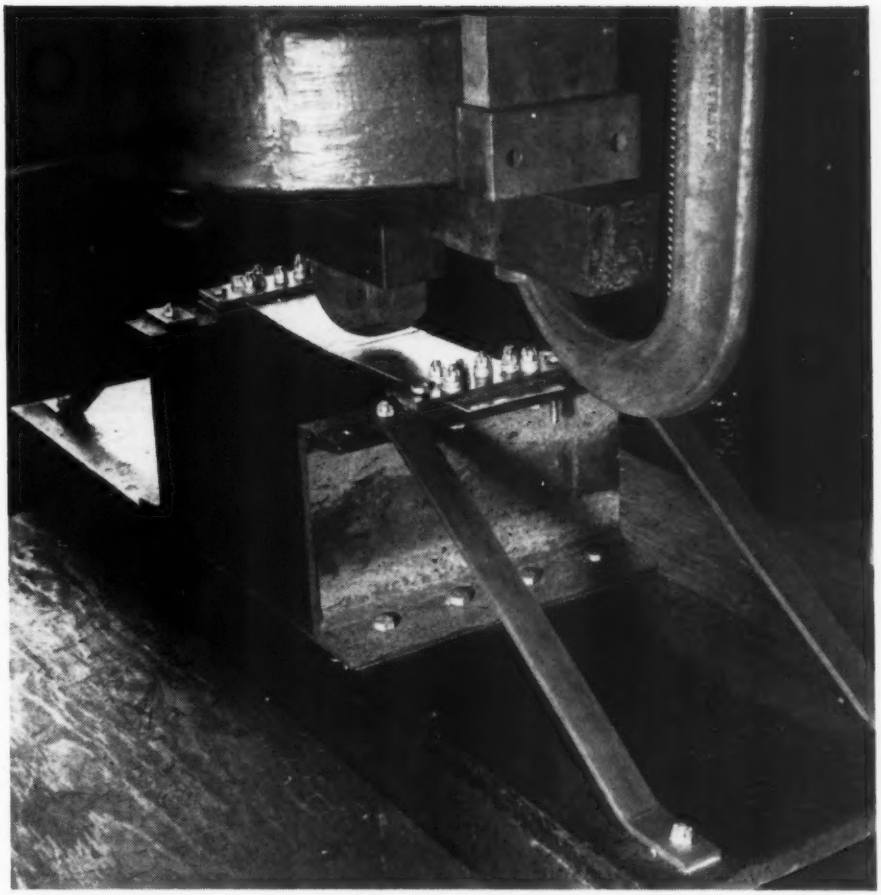


Fig. 4—Specimen sheet fastened in jig ready for ductility test. Jig rests on platen of testing machine. Ends of specimen are bolted between steel plates on channel irons.

CORROSION RESISTANCE. It is reported by Spacht that the wrought and cast aluminum-magnesium alloys are the most resistant of any aluminum alloys to alkaline attack (See, R. B. Spacht, "The Corrosion Resistance of Aluminum and Its Alloys", *Jour. Chem. Ed.*, Vol. 23, May 1946, pp 253-57). Such resistance is a direct function of the magnesium content. P. Brenner and F. Plattner (See, An abstract of German authors, "Corrosion of Aluminum Alloys", *Metals and Alloys*, Jan. 1941, p. 100) in corrosion tests conducted over a period of $3\frac{1}{2}$ years, discovered that the Al-Mg-Si sheet alloys ranked slightly below the binary Al-Mg alloys in resistance to atmospheric attack.

In marine atmospheres R. B. Mears and R. H. Brown, (See, "Resistance of Aluminum Base Alloys to Marine Exposures," *Marine Eng.*, Dec. 1944, pp 170-1), state that 61S-T is but slightly less resistant than the alloys listed above it in Table IV. No appreciable difference appears between the precipitation heat-treated and other

Table III—Work-Hardening of 61S-W Sheet

Condition	Yield Strength 0.2% Set, psi	Tensile Strength psi	% Elong in 2 in.
Unstrained	19,800	35,100	19.8
Stretched 5%	33,200	39,500	13.6
Hammered 5%	34,900	40,500	9.0
Stretched 5%, Hammered 5%	36,500	40,600	9.0
Stretched 5%, Hammered 10%	39,100	43,900	6.7

tempers, and slow cooling has but little effect on the behavior. The observations of the writer indicate that there is very little difference in reaction between the first six alloys listed in Table IV, whereas the differences between the alloys 53S and 61S and the alloys 17S and 24S are so great that the value of the listed merit ratings is distorted. The suggested order of merit given in the third column of Table IV establishes a more accurate comparison.

COST. The basic price of 61S when compared with equivalent thicknesses, sizes, and tempers of other aluminum sheet alloys, is less than any except 2S and 3S. Table V gives the latest available prices for flat and coiled sheet, based on a thickness of 16 gage (0.064 for flat and 0.061 for coiled sheet), and a minimum weight of 30,000 pounds. For flat sheet, the comparative size is 48x144 in. and for coiled sheet width is 24 inches.

ACKNOWLEDGMENT: The author thanks R. R. Wiese and W. J. Wilson both formerly with Kaiser-Fleetwings, Inc., and E. A. Foster of the Aluminum Company of America, for their valuable assistance in the preparation of this article.

Table IV—Resistance of Aluminum Base Alloys to Marine Exposures

Atmospheric Exposure Near The Sea

Alloy	Order of Merit (Mears)	Suggested Order
Alclad 24S-T and Alclad 17S-T	1	1
2S and 52S	2	
53S-T and 61S-T	3	2
17S-T and 24S-T	4	

Exposure to Sea and Harbor Waters

Alloy	Order of Merit (Mears)	Suggested Order
Alclad 24S-T and Alclad 17S-T	1	1
52S	2	
53S-T and 61S-T	3	
17S-T and 24S-T	4	2

Table V—Aluminum Alloy Sheet Costs

Flat Sheet		Coiled Sheet	
Alloy and Temper	Cents per lb	Alloy and Temper	Cents per lb
2S-½H	25.5	2S (all)	23.4
3S-½H	25.5	3S (all)	23.4
52S (all)	29.7	52S (all)	26.5
61S-O	27.7	61S (0 and as rolled)	25.0
61S-W	30.2		
61S-T	30.7		
24S-O	28.7	24S (0 and as rolled)	27.0
24S-T	31.7		
R301-O	28.0	R301 (0 and as rolled)	26.2
R301-W	30.5		
R301-T	31.0		
75S-O	36.0	75S (0 and as rolled)	29.7
75S-T	40.9		

Vibration Generator Tests Ship Strength

VIBRATION GENERATORS, originally suggested in Germany during the late 1920's are being used on a larger scale according to a recent report issued by the Office of Technical Services. The report, prepared by E. O. Berdahl of the David Taylor Model Basin, discusses United States Navy use of vibration generators to investigate dynamic characteristics of ships, bridges and other large structures.

Initial use of vibration generators was to set ship structures in resonant vibration so relative stiffness of the structure could be determined with recording instruments. If the natural frequency and corresponding stiffness of the ship were found to be lower than estimated satisfactory values, it was concluded that either ship joints were not sufficiently rigid or design of ship was incorrect.

This generator, purchased from Germany in 1931, develops a vertical sinusoidal force with a maximum single amplitude of 44,000 lb at speeds from 105 to 480 rpm. It will generate a comparable maximum force of 11,700 lb in the same direction at its lowest running speed of 54 rpm. Operated on d-c power, the total rated power consumption of the two driving motors is 30 kw. The complete apparatus weighs 49,500 pounds.

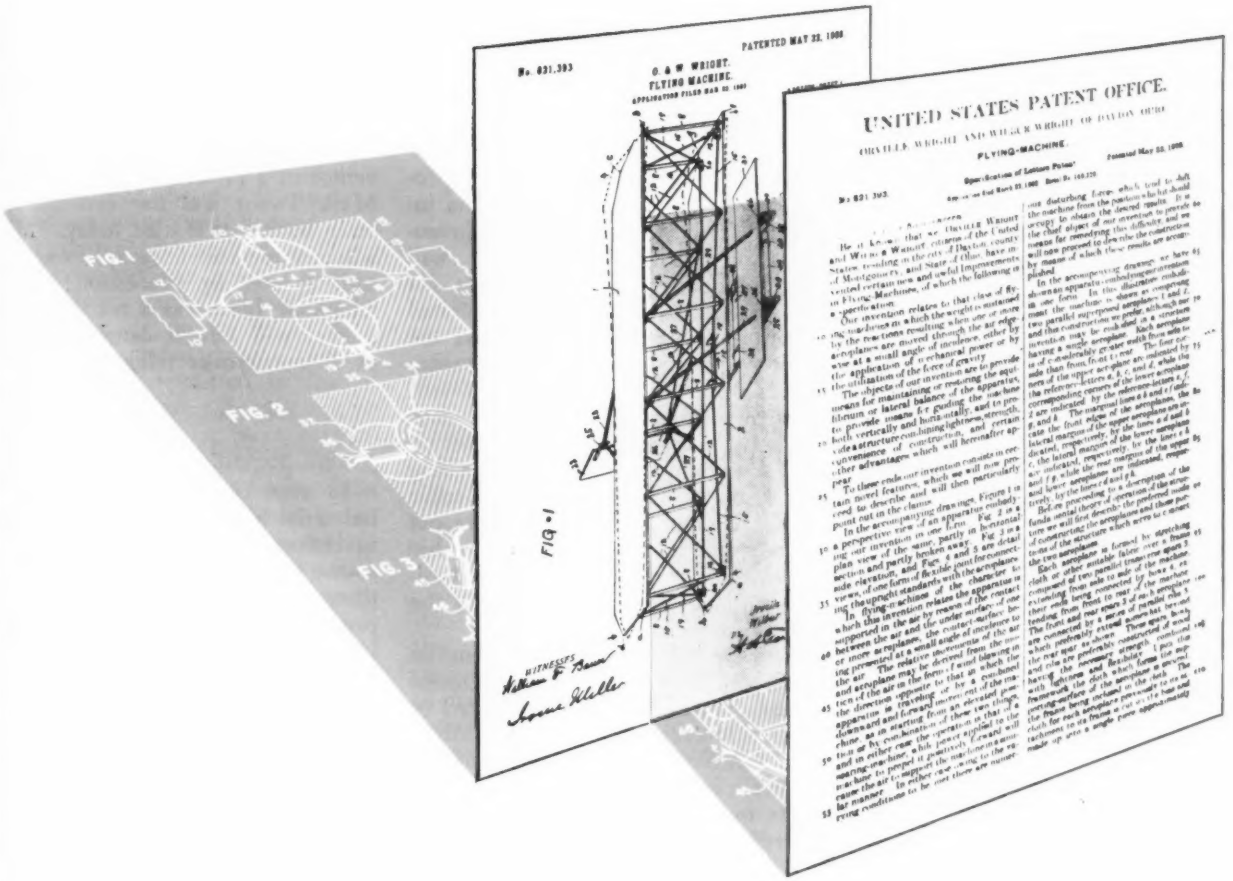
The machine consists of two parallel shafts geared together by two large single helical gears on one shaft. This arrangement ensures synchronous rotation of the two main shafts in opposite directions. Each main shaft is driven by a d-c motor through reduction gear trains with ratios of 6 to 1 or 16 to 1. Each shaft carries a 6,000 lb eccentric that can be adjusted to various amounts of unbalance. The machine base must always be horizontal and the magnitude of the exciting force is directly proportional to the unbalance. In operation, the vibrator is run at resonance while the structure under study is explored with instruments to determine its mode of vibration.

On ships, units can simulate exciting forces of shaft and blade frequencies and can indicate speeds likely to produce resonance in operation. It can also be used to determine stiffness of bridges, effective masses and natural frequencies. It may even be used to measure the excitation given a bridge by such forces as the drivers of a steam locomotive. It is a practical way of determining periodically whether a change has taken place in the stiffnesses of bridge structures.

Another possible application is to use the generator to relieve the stress of welded structures. The technique consists of creating dynamic stresses which, when added to the locked in stresses in the structure, will cause the yield point of material to be exceeded with consequent plastic flow.

Vibration generators of various sizes and capacities have been used in Germany. Large units have been used to determine the stiffness of building foundation sites and road beds in order to anticipate difficulties caused by uneven soil settling.

The report (PB-81751; "Construction and Operation of the Losenhausen 44,000 lb Vibration Generator", 31 pages, 1947) sells for $4 per photostat copy, and $1.75 per microfilm copy. Orders should be addressed to Office of Technical Services, Department of Commerce, Washington 25, D. C. and accompanied by check or money order payable to the Treasurer of the United States.



Patents and the Engineer

PART ONE

Patents, and the protection of inventive ideas, are both misunderstood subjects in the engineering profession. Attitudes range from secrecy to lack of record-keeping, which leads to inadequate protection.

By
H. A. TOULMIN, JR.
Toulmin & Toulmin

With normal business competition again regulating the American economy, patent protection is assuming ever-increasing importance. This great interest coupled with evident widespread misunderstanding of our patent system, prompted H. A. Toulmin, Jr., nationally known patent attorney, to write a detailed analysis and guide for the use of engineers and others not experienced in patent law.

Product Engineering presents this special report in two parts. Part I deals with patent procedure, Patent Office rules, and the many methods for testing and protecting patentable inventions.

The American Patent System

★ ★ ★ ★ ★ ★ ★ ★

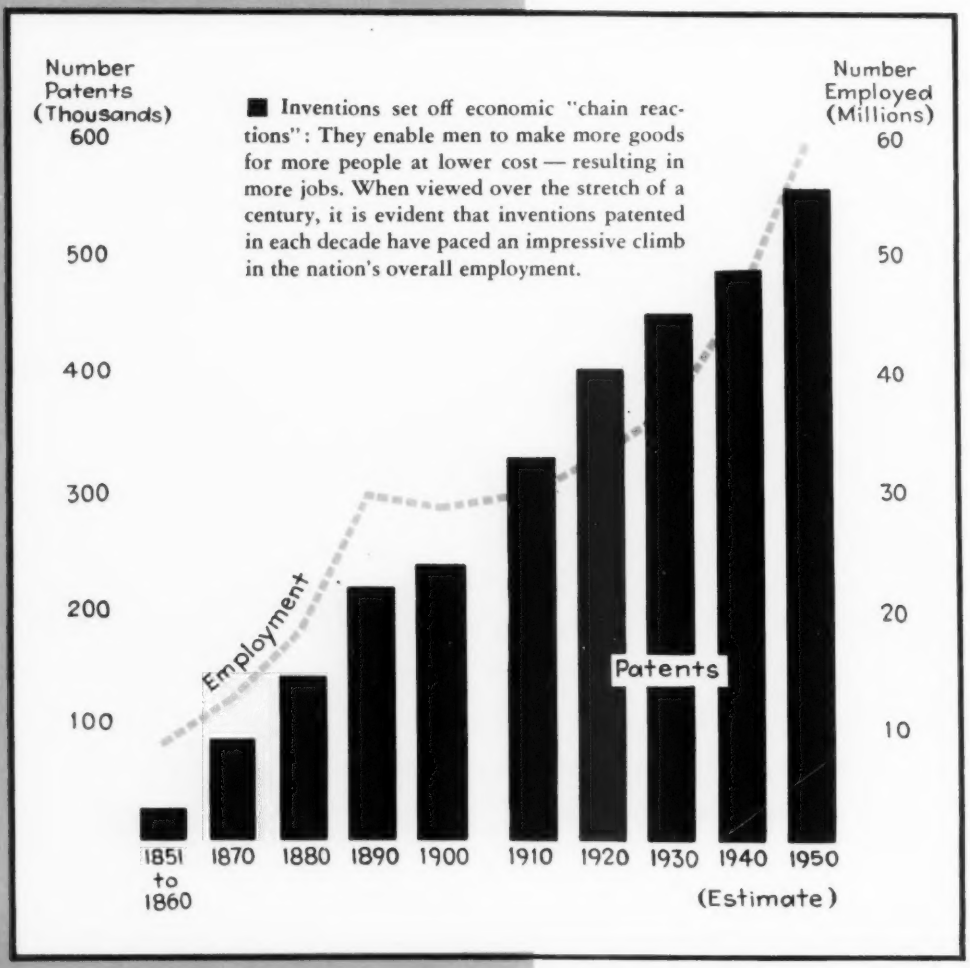
"To promote the Progress of Science and useful Arts, by securing for limited Times to Authors and Inventors the exclusive Right to their respective Writings and Discoveries."

—THE CONSTITUTION OF THE UNITED STATES

★ ★ ★ ★ ★ ★ ★ ★

THE AMERICAN SYSTEM of patent protection is unique. We say to the inventor: "If you will make an invention of public benefit and will disclose that invention promptly for the stimulation of industry, the United States government will give you the right to exclude others from manufacturing, using or selling that invention for a period of seventeen years. You will not have to pay any taxes on that invention because we are going to rely on the good sense of the people of the United States to help you put your invention into practice, if it has merit. The resulting increase in business will be worth more than all the taxes that we can get."

Because of the free opportunities available to inventors in the United States, invention has been practiced by practically every sort of person. Abraham Lincoln was an inventor of the "water camel", a device for lifting boats over sand bars in mid-western rivers. Thomas Jefferson was the inventor of a plow, as was Washington. Mark Twain was the inventor of a scrap book that is used today. Morse, who invented the telegraph, was a portrait painter by profession; Bell of telephone fame was a teacher of deaf mutes; and Edison earned his living as a journeyman telegraph operator.



■ Inventions set off economic "chain reactions": They enable men to make more goods for more people at lower cost — resulting in more jobs. When viewed over the stretch of a century, it is evident that inventions patented in each decade have paced an impressive climb in the nation's overall employment.

Economic Importance of Invention

In some of the great periods of industrial history in the United States, inventions changed the economic course of our country. There were three great eras of manufacturing prosperity and advancement in the United States, which coincide with the three great eras of invention.

The first period was from 1780 to 1830; the second from 1830 to 1880; the third period from 1880 to 1947. The first period was the conversion from artisanship at home to factory manufacture. The second period was the integration of factories into specialized intra-state establishments, organized along functional lines, such as foundries, machine shops, forge shops, and the like. Factory organization characterized the third period—engineering principles were applied to management, financing and corporate organization.

From 1780 to 1830, introduction of the steamboat on the great American rivers marked the beginning of the age of steam and waterborne transportation. From 1830 to 1880 the Pullman car and the revolution caused by the Westinghouse airbrake made high speed mass railroad transportation possible. From 1880 to 1946 the automobile, telephone, business machines, carborundum, the Hall process of obtaining pure aluminum, and radio, based on activities of Marconi, DeForest, and Pupin, were developed.

What has been the economic result of inventions?

In the period from 1873 to 1923, including average times of prosperity and depression, our population increased 158 percent, total wealth increased 753 percent; while per capita wealth rose 223 percent, or from 830 to 2,689 dollars per person. Bank deposits grew 1,758 percent and the value of manufactured goods 1,366 percent; compare this with an agricultural growth of 336 percent, showing a marked trend towards industrialization and capital wealth.

Characteristics of Invention

THIS DISCUSSION is concerned only with patentable inventions, for this is the only type considered by the Patent Office and the courts.

A patentable invention is a concrete, workable expression of an idea that is new and useful. It can be a new and useful proposal derived from an old combination of parts or steps in a process; or from a new combination; or from partly old and partly new elements or steps. It can be a new article of manufacture, a process, a machine, a composition of matter, a plant, or a design. It must not be merely a thing that is more convenient, easier to operate, cheaper, lighter, adjustable, simpler, or any one of the ordinary comparative advances in an industry resulting from the application of ordinary mechanical skill, standard electrical technique, or engineering or scientific knowledge.

Art or Process

A manufacturing process is clearly an "art", within the meaning of the law. Goodyear's patent was for a process—vulcanizing india-rubber by subjecting it to a high temperature when mixed with sulfur and a mineral salt. The apparatus for performing the process was not patented, and was not relevant to the patent. In Nielson's patent for applying a hot-blast to furnaces by forcing the blast through a vessel situated between the blowing apparatus and furnace, the form of the heated vessel was stated by the patent to be immaterial.

Machines

The term "machine" as used in the patent statute includes every mechanical device or combination of power units and devices to perform a function and produce an effect. However, a person cannot describe a machine that will perform a specified function, and then claim he has patented the function itself and all other machines that might be invented to perform such a function. Function is not patentable as defined in the statute.

Manufactures

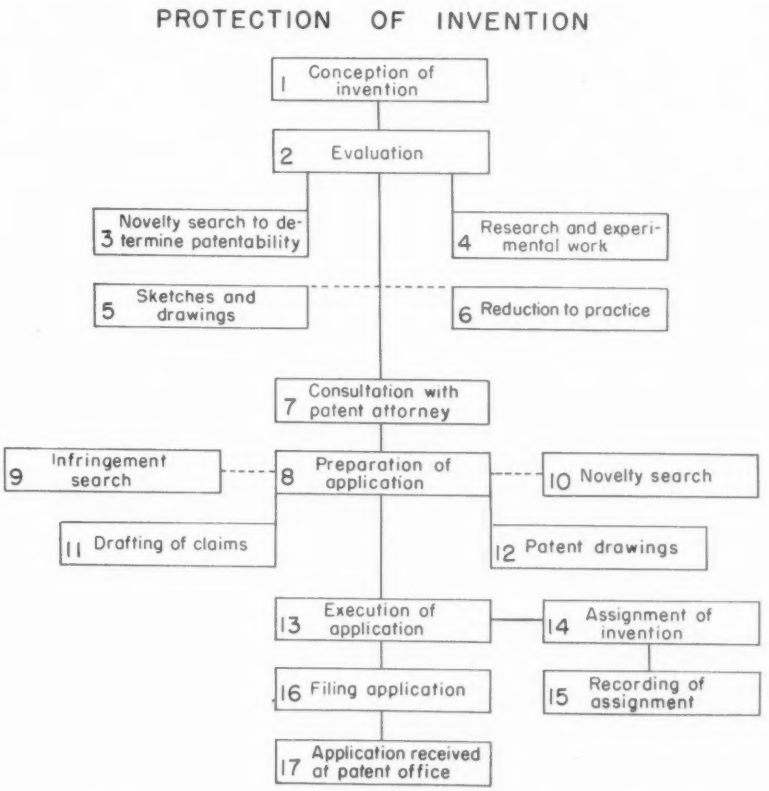
The term "manufacture" as used in the patent law, has a comprehensive sense, embracing whatever is made by man, not including a machine, a composition of matter, or a design. Articles of manufacture can be new in the commercial sense, and not new in the sense of the patent law. New articles of commerce are not patentable as new manufactures, unless it is proven that the production of the new article involved the exercise of invention or discovery beyond what was necessary to construct the apparatus for its manufacture or production.

Improvements

Mere improvement without invention is not patentable, and the fact that a substituted device is greatly superior to the one it replaces is not of itself proof of invention. To be patentable, improvement must be a product of original conception—the more extended application of an original idea is not invention.

The law regards a change as evidence of novelty. It also recognizes degree of change, dividing inventions into primary and secondary, and giving proportionate dominion to the claims granted. Thus, an invention can be broadly new, subjecting all that comes after it to tribute; or, it can be only a step in a series of developments, and limited, therefore, to its precise form and elements. The latter type has as firm a right to protection as the former.

A patent for an improvement will be granted if invention is proved, even though the patentee of neither the original device nor the improvement can use his invention alone. This may lead to a deadlock. The only way out of such a situation is by common ownership or cross licensing.



The steps between conception of invention and the Patent Office are many and well defined. Each step is equally important, and requires careful thought if the patent is to be valid.

Composition of Matter

According to a court decision: "A patentable composition of matter may well result or be formed by the intermixture of two or more ingredients, which develop a different or additional property or properties which the several ingredients individually do not possess in common."

The discovery, that acetone used as a solvent for acetylene gas made a solution having none of the explosive properties of either substance singly and therefore could be safely handled, was held patentable.

Designs

The Act of Congress which authorized the grant of patents for designs contemplated appearance more than utility. It is not the manner in which the appearance is produced but the appearance itself, that is the patentable element.

Some designs can be protected under the design patent law, the copyright law, or the new trademark law, and the owner of the design can choose the law under which he will seek protection.

Scientific Principles

Scientific principles and laws of nature belong to the common storehouse of public knowledge. Therefore, discoveries that reveal new fundamental scientific principles are not patentable. However, as soon as such a discovery is given a concrete application for the creation of a new art, or the advancement of a known art, it becomes invention.

Personal Factors

Legally, an inventor can only be a natural person, not a corporation. When two inventors work together for a common end, finally accomplished by the contributions and united efforts of both, the invention is joint. Neither can secure a valid patent as the sole inventor.

Even when one person conceives the entire invention, and another makes a suggestion needed to make the conception a success, it makes them joint inventors.

A person directing others to carry out his general ideas can be an inventor, even though he is not the actual discoverer of the particular thing that constitutes the final invention. The accomplishment of the associate is considered an expression of the intellectual activity of the principal.

Because the law protecting invention is based on the idea of promoting public welfare, it requires that the patent be sufficiently explicit to enable others to benefit from the ideas. The proposer must have something more than a general idea; he must show in what manner it can be done.

The necessity for making claims complete was dramatically illustrated in a patent application for an apparatus for softening water. It disclosed a process of softening water by means of "zeolites" which, after removing calcium and magnesium from hard water, and giving up their sodium base, are regenerated when washed by a salt solution. The patentee claimed an arrangement and a process for preventing "locking" of the zeolites, which interfered with their efficient action. The invention relied on the removal of a close-fitting cover and the placing of a screen some distance above the layer.

The patentee failed to mention this feature in the specification or claims. The patent was found invalid, and the court held there was no invention in placing the means for removing the salt solution at the lowest point, as it did not require the exercise of the inventive faculty to place at the bottom of a receptacle the only outlet through which it could be drained.

It is not necessary, however, that the practical disclosures be carried so far that the patent is merely a bill of materials or a list of operating instructions for commercial practice.

The law encourages sufficient delay on the part of the inventor, before he makes his disclosure, for him to determine that his invention is workable. However, an inventor must not abandon his idea, but must complete it and disclose it promptly. If he drops it and another person completes it and makes it known to the public, then the second person is the inventor. Invention is based on successful accomplishment. Mere experimental work is not recognized as invention.

The standard of success can be low; the invention need not have achieved complete commercial form. It need not be in such shape that it can be sold to the public. The invention must merely be sufficiently operable so that any one skilled in the art, by applying knowledge and engineering talent in that art to the proposal of the inventor, could make it practicable.

The latter step is not necessary on the part of the inventor. Most important inventions have been crude in their initial stages, but their disclosures have been sufficient to teach the principles involved and to show the way to full utilization of the invention. That is all the law requires.

It is not important that the inventor specify all the uses to which his invention can be put. To mention one legitimate use is sufficient. It would be impossible for the inventor to predict the wide range of uses to which his invention might be applied over a period of seventeen years.

Patent Procedure

THE INVENTOR usually passes through the first stage of speculation, investigation and finally conception. This takes place first in his mind and then in drawings and sketches. Then follows reduction of the development to a working model, to enable tests of the workability of the idea to be made.

As far as the patent law is concerned, an inventive idea can be merely on paper; if it is clear, workable, and new, a valid patent can be obtained. For commercial reasons, however, it is desirable that some development work be done. It is usually safer for the average inventor to do this work before securing a patent rather than do it later in haste.

The patent application consists of a petition; specification; oath; a drawing if necessary; claims; filing fee; and usually a power of attorney to the lawyer, which authorizes him to act before the Patent Office on behalf of the inventor.

The first step in obtaining a patent is to furnish a patent lawyer with a description of the invention, together with drawings, photographs or a model. An inventor can file and prosecute his own application, but he will not find it easy to do this in view of complex Patent Office practice. The attorney should be qualified to practice before the United States Patent Office, and must be on the roster of such attorneys, in good standing. A patent attorney should be skilled not only in law, but also in the arts and sciences, preferably in engineering. He should have had practical experience in patent litigation in the United States courts.

The attorney will search the Patent Office records in Washington and the

literature of the particular art, to see whether the idea is new. If he finds it new, he prepares a description of the invention stating its objectives, its accomplishments and how it works. He refers to numbers on the parts in the drawings that accompany the description.

Specification

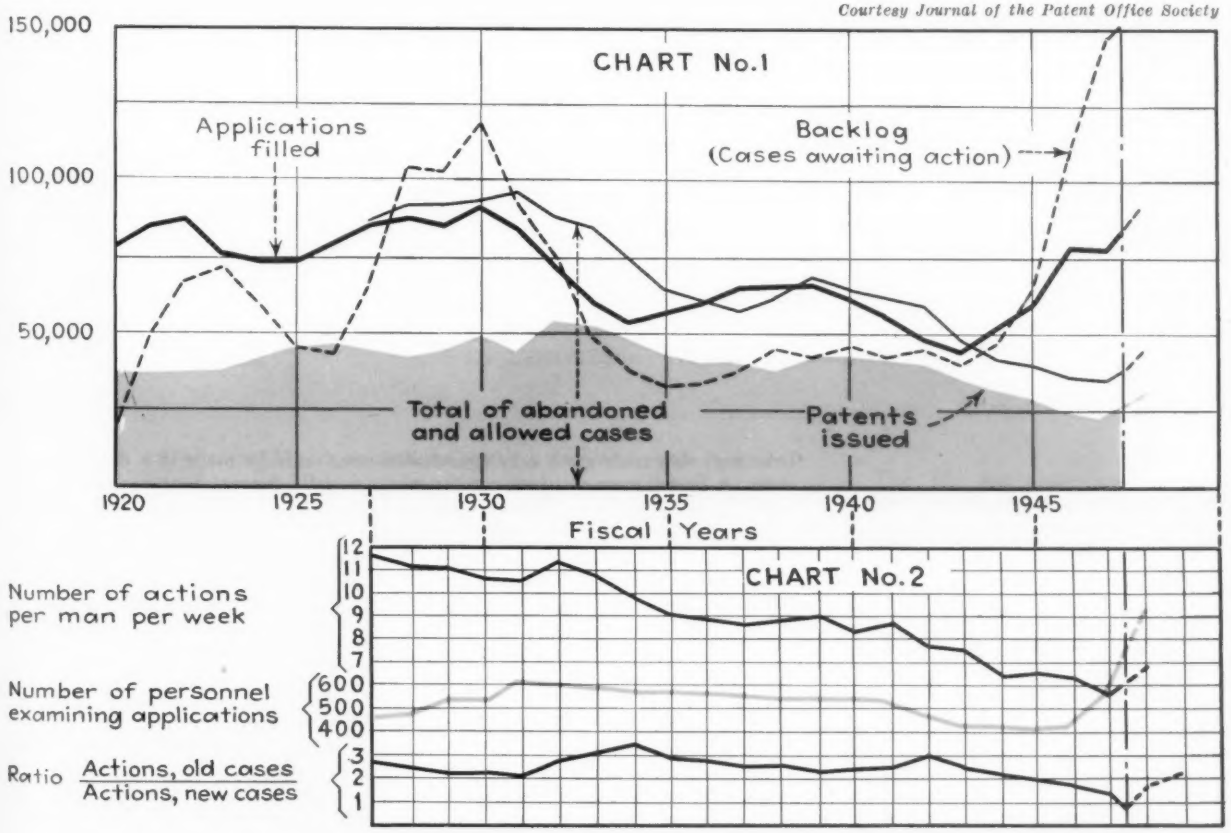
The scope of every patent is limited to the invention described in the claims, and in accordance with the specification. According to the courts: "The specification and claims of a patent constitute a contract between the United States and the patentee and they should be read and construed together, not for the purpose of limiting, contracting, or expanding the claims, but for the purpose of ascertaining from the entire agreement the actual intent of the parties." However, the claims, not the specifications afford "the measure of the grant to the patentee."

The specification concludes with a series of numbered paragraphs, called "claims". Each of these claims covers the particular property of the invention which the inventor hopes to monopolize. Some of the claims are broad and are usually brief. Others are somewhat narrower and more detailed, and some include practically all of the separate elements.

In making up his claims, the inventor should keep in mind that there are several classes of patents: Mechanical patents for manufactured products and machines—these include electrical, aerodynamic, and hydraulic constructions; chemical patents for materials and chemical processes; and design patents, which cover form and appearance, usually emphasizing artistic features not essential to mechanical operation of the device.

Patents can be classified in another way: Some deal with the apparatus itself, and others cover the method of operation of the apparatus. An apparatus patent, for example, can have claims that call for the combination of a wheel, an axle, a body, and a steering gear. In a method patent claims must not be tied down to any particular mechanism. The number of necessary claims is not limited.

Courtesy Journal of the Patent Office Society



WHY THE PATENT OFFICE IS TWO YEARS BEHIND

Many war and civilian developments are being kept out of use because of enormously increased work-load imposed on the Patent Office. There are 150,000 cases awaiting action, and the examination of applications is two years behind. Applications now are being received at an annual rate of 70,000, nearly double the 1943 rate.

These factors are responsible:

1. Overcrowded facilities. At present 40 percent more personnel occupy 20 percent less space than before the war.

2. Inexperienced examiners. Today, 40 percent of examiners have less than two years' service.

3. Increasing volume of literature to be searched. Increasing numbers of technical publications, books and patents lengthen time of search.

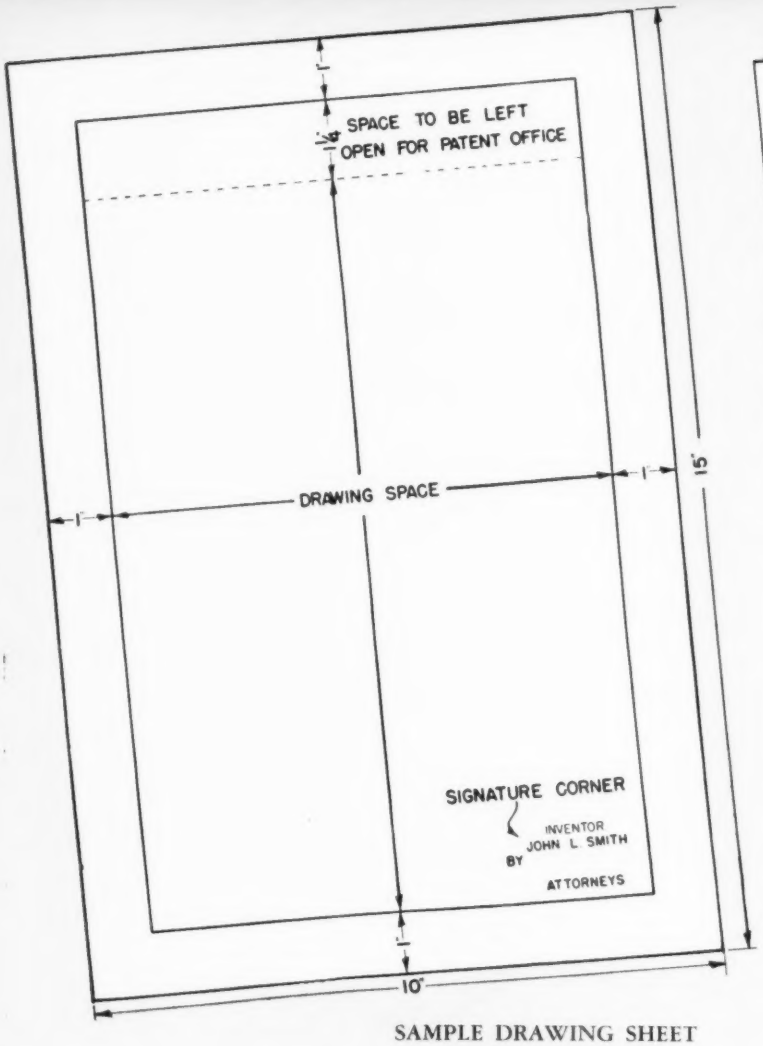
4. Increasing complexity of cases. New complex discoveries make simple examination impossible.

5. Contraction of examining corps. Examiners experienced in special fields, lost through war or other reasons, caused examiners to work in unfamiliar fields—slowing operations.

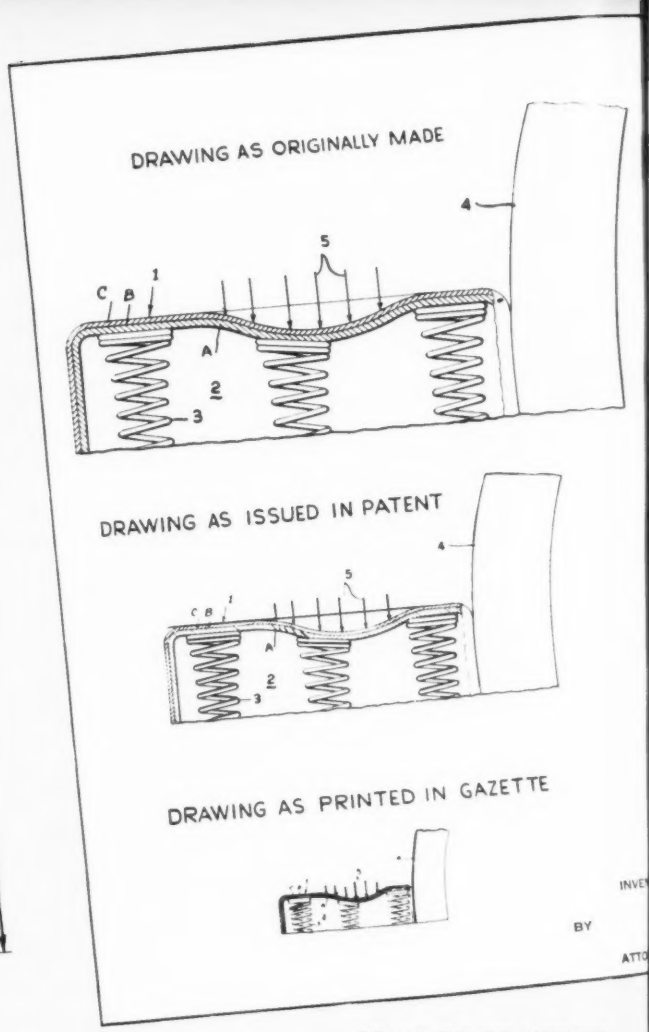
6. High proportion of new cases in work load. Initial actions require more time than final actions.

7. Rising importance of validity. If careful job is not done, patents held invalid by courts will cause lack of confidence in patent system.

8. For an effective patent, greater detail is demanded by the Patent Office than formerly. This adds to the decline in patents issued, but not necessarily to the backlog, since in certain fields so much work is entailed, that many cannot afford to apply.



SAMPLE DRAWING SHEET



SCALE OF DRAWINGS

Drawings that accompany a patent application should be made in a definite size and style. A better drawing does not guarantee a valid patent; however, anything that can be done to point out salient features of the invention to the examiner will save

Drawings

The drawings accompanying a patent and its claims are illuminating when the question of prior art and intended coverage is at issue. Drawings can be referred to for illustration and can be used to interpret the specification or claim. Drawings cannot fill the absence of a written description; however, they serve to add clearness and certainty to what is actually described.

The description of an invention as contained in the claims, interpreted in the light of the specifications, is neither restricted nor extended by the drawings. An evident mistake in a figure in the drawings will not render a patent invalid.

When the application is filed in the Patent Office it is accompanied by a government fee of thirty dollars, with an additional fee of one dollar for each additional claim over twenty. The application is then assigned to the particular part of the Patent Office which examines that class of inventions.

After the application is filed and examined by the examining division, the Patent Office replies to the attorney, allowing or rejecting the claims and indicating any objections to the drawings, or the subject matter of the specification and its wording. Usually the Patent Office refers to anticipating patents and publications, which must be ordered, studied, and discussed in detail when replying to the Patent Office. The inventor or his attorney has six months to reply to this action. Failure to reply to the Patent Office, or an incomplete response within six months after the Patent Office replies to the inventor or his attorney, causes abandonment of the patent. Under certain conditions, it can be restored.

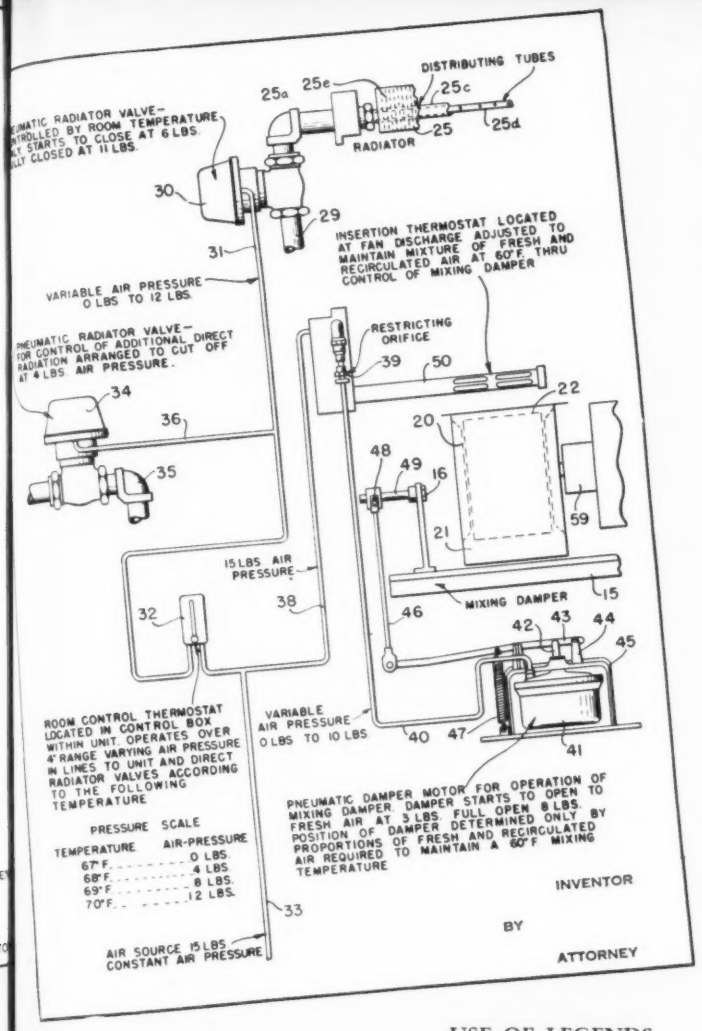
At this stage the applicant, or his attorney can amend the claims, so they will not conflict with the prior art; or he can cancel them; or his answer can be a combination of claim cancellation, amendment and argument. This correspondence terminates in a final allowance or final rejection of the application.

Upon final allowance, the final fee of 30 dollars is paid and the patent is made ready for issuance. When it is issued, a summary of it is published in the Official Gazette of the Patent Office.

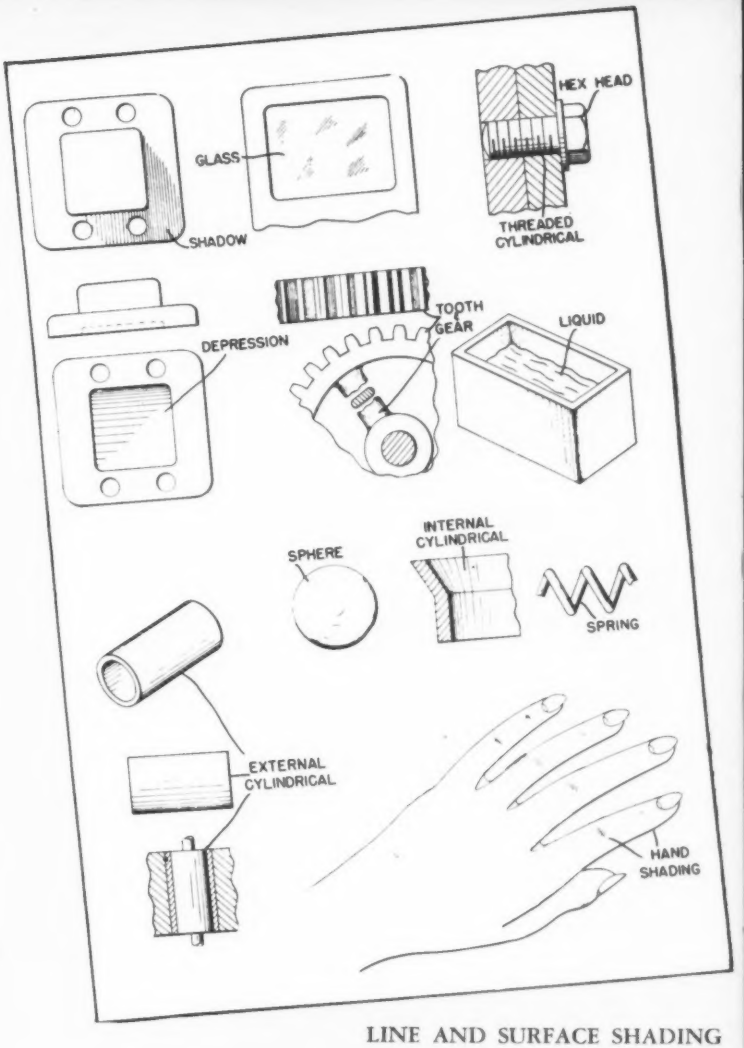
Patent Office Rules

The Patent Office operates under "Rules of Practice" drafted by the Commissioner of Patents and approved by the Secretary of Commerce. Among the most important of the rules are those defining the nature of a patent application: Rules 26, 30, 31, 33, 40, 46, 49, 77, 171, 172 and 173. Copies are available in the Patent Office.

An inventor can prosecute his own application, but he will not find this an easy matter, in view of complex Patent Office practice. If an attorney is employed, he should be on the roster of attorneys qualified to practice before the U. S. Patent Office.



USE OF LEGENDS



LINE AND SURFACE SHADING

time, and avoid possible litigation later. Drawings also help determine intended coverage. Information as to size, lettering, shading, dimensions, standard symbols and other patent drawing practice can be obtained from the U. S. Patent Office.

The File Wrapper

THE FILE WRAPPER HISTORY of a patent application is the complete file starting with the original papers as filed in the Patent Office, and continuing until the application is finally allowed or rejected. These papers are preserved in the Patent Office for twenty years. Changes made in the original application are indicated by pen corrections on the first of the original papers. These corrections are made by the Patent Office, under the authority of each reply from the applicant or his attorney.

If the application becomes abandoned or finally rejected, the papers remain secret unless opened under special conditions. If, however, the patent is allowed, the file wrapper history becomes public, and any one may order a copy of it. The accompanying illustration shows a typical Patent Office action, a reply, and the corrections made on the original specification and claim as the result of these written negotiations.

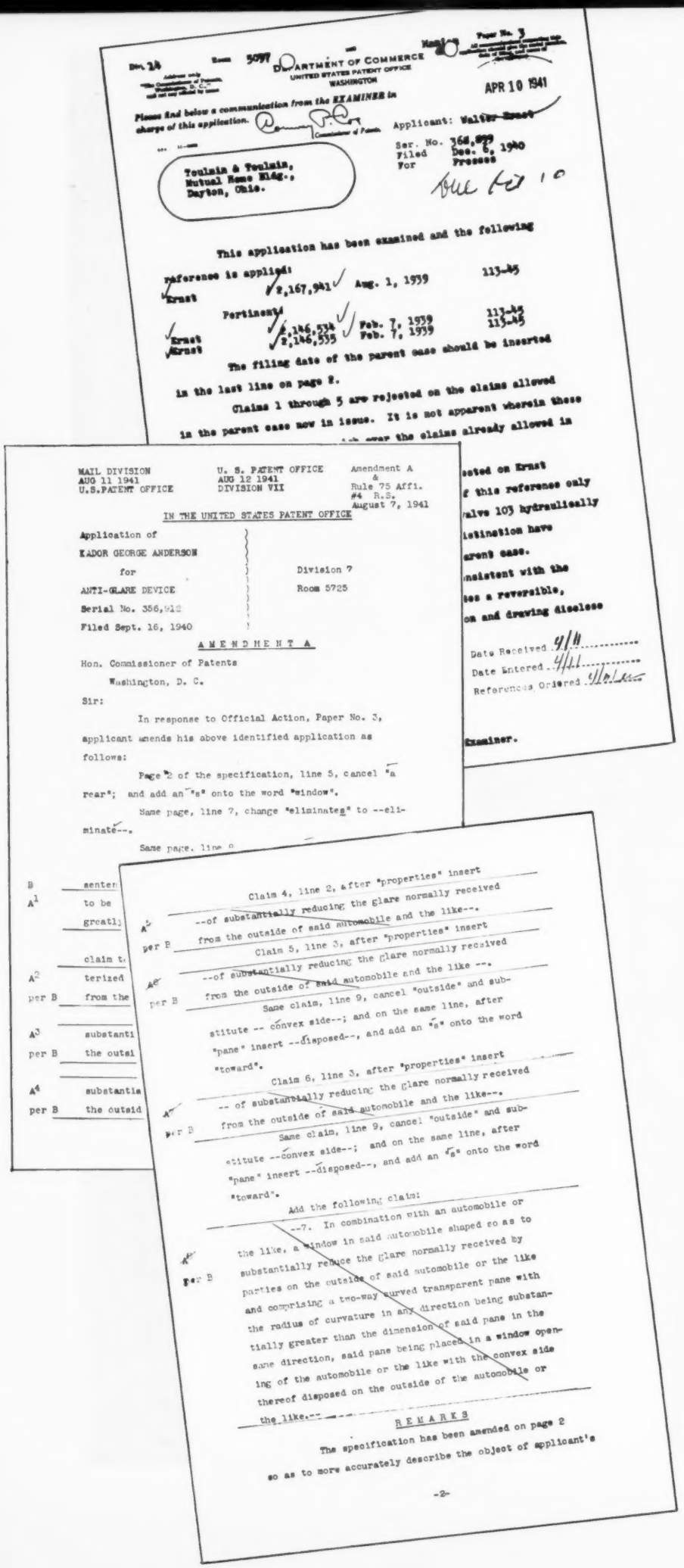
The contents of a file wrapper cannot be used to test a patent. Its only uses are: (1) to interpret the language of a patent, when that language might have two different, but legitimate meanings; and (2) to prevent a patentee from applying to the claim a meaning inconsistent with its history.

The file wrapper is just as much a matter of public record as the patent, and is as much of a notice and warning to the public as if it were contained in the patent itself.

The file wrapper cannot be used by the patentee to interpret his specification and claims. Interpretation must come from the claim itself.

However, sometimes the file wrapper is involved in a procedure called "estoppel". In this process, a patentee, to avoid rejection of his application, inserts limitations in his claims. Later he is prevented from contending that the issued patent should be construed as if such limitations had not been made. While it involves looking at preliminary negotiations in the interpretation of the patent intended to be the final statement of the patentee's intention, the practice is well settled for the reason that the docrine of estoppel holds "the utterer to the truth of his speech." Usually this procedure is known as "file wrapper estoppel", because it involves examination of cancelled claims in the file wrapper. This is the only time when Patent Office proceedings affect the specifications of the final patent.

When a patent is alleged to be infringed in court, invalid claims can not be "settled" with estoppel procedure.



DEPARTMENT OF COMMERCE
UNITED STATES PATENT OFFICE
WASHINGTON

APR 10 1941

Please find below a communication from the EXAMINER in charge of this application.

Commissioner of Patents

Applicant: Walter Ernst

Ser. No. 368,899
Filed Dec. 6, 1940
For Process

Toulmin & Toulmin,
Mutual Home Bldg.,
Dayton, Ohio.

This application has been examined and the following reference is applied:

Ernst 2,167,941 Aug. 1, 1939 113-45

Pertinent:

Ernst 2,146,534 Feb. 7, 1939 113-45
Ernst 2,146,535 Feb. 7, 1939 113-45

The filing date of the parent case should be inserted in the last line on page 2.

Claims 1 through 5 are rejected on the claims allowed in the parent case now in issue. It is not apparent wherein these ... over the claims already allowed in ... ected on Ernst ... f this reference only ... valve 103 hydraulically ... istination have ... arent case. ... nsistent with the ... es a reversible, ... on and drawing diseless

Date Received 4/11
Date Entered 4/11
References Ordered

Examiner.

MAIL DIVISION
AUG 11 1941
U.S.PATENT OFFICE

U. S. PATENT OFFICE
AUG 12 1941
DIVISION VII

Amendment A
&
Rule 75 Affi.
#4 R.S.
August 7, 1941

IN THE UNITED STATES PATENT OFFICE

Application of
KADOR GEORGE ANDERSON
for
ANTI-GLARE DEVICE
Serial No. 356,912
Filed Sept. 16, 1940

Division 7
Room 5725

AMENDMENT A

Hon. Commissioner of Patents
Washington, D. C.

Sir:

In response to Official Action, Paper No. 3, applicant amends his above identified application as follows:

Page 2 of the specification, line 5, cancel "a rear"; and add an "s" onto the word "window".

Same page, line 7, change "eliminateg" to --eliminate--.

Same page, line 8

B senter
A1 to be
greatl
claim t
A2 terized
per B from the
A3 substanti
per B the outsi
A4 substantia
per B the outsid

Claim 4, line 2, after "properties" insert
A5 --of substantially reducing the glare normally received
per B from the outside of said automobile and the like--.

Claim 5, line 3, after "properties" insert
A6 --of substantially reducing the glare normally received
per B from the outside of said automobile and the like --.

Same claim, line 9, cancel "outside" and substitute --convex side--; and on the same line, after "pane" insert --disposed--, and add an "s" onto the word "toward".

Claim 6, line 3, after "properties" insert
A7 -- of substantially reducing the glare normally received
per B from the outside of said automobile and the like--.

Same claim, line 9, cancel "outside" and substitute --convex side--; and on the same line, after "pane" insert --disposed--, and add an "s" onto the word "toward".

Add the following claim:

A8 --7. In combination with an automobile or
per B the like, a window in said automobile shaped so as to substantially reduce the glare normally received by parties on the outside of said automobile or the like and comprising a two-way curved transparent pane with the radius of curvature in any direction being substantially greater than the dimension of said pane in the same direction, said pane being placed in a window opening of the automobile or the like with the convex side thereof disposed on the outside of the automobile or the like.--

REMARKS

The specification has been amended on page 2 so as to more accurately describe the object of applicant's

-2-

Mistakes and Corrections

It does not matter that a patentee is mistaken in stating the theory of his invention, if he fully describes the invention itself and its practical results, and gives sufficient directions for putting it into practical use. The law requires nothing more.

In one patent the specification unnecessarily contained a scientific theory concerning the action of aluminum. The inventor thought the aluminum acted to lower the melting point of the mixture and thereby rendered it more fluid. Later, the generally accepted explanation of the phenomenon following the addition of aluminum was that the aluminum acted as a deoxidizing agent. The patent was held valid because the inventor had fully described his invention and the result, and gave directions for putting it into use.

A patent can invoke in support of his invention advantages of which he was not aware, at the time of filing, but the patent must disclose them. As one court decision put it, "The patentee may have builded better than he knew, but he is confined to what he built."

However, if an inventor comes to better understand the principles of his invention while his application for a patent is pending, an amendment of his claim that does not introduce any original matter nor enlarge his invention is within his legal rights.

It is not necessary that the patentee understand or be able to state the scientific principles underlying his invention and "it is immaterial whether he can stand a successful examination as to the speculative ideas involved." Another court said:

"It is no concern of the world whether the principle upon which the new construction acts be obvious or obscure, so that it inheres in the new construction."

An introductory phrase is not generally considered a limitation or part of the subject matter of the claim. A preliminary statement such as "In a machine of the class described, the combination . . . ." is merely used to specify the type of machine in which the claimed combination of elements is an improvement over the prior art.

Correspondence and other vital information, which concern the patent and are in the file wrapper, are not "frozen." Changes and amendments can be made freely, directly on the document involved, providing that all parties concerned, and the Patent Office, agree to the changes.

Amendments

Amendments in the description or drawing of a patent application do not invalidate the patent, if they merely amplify and explain what is already reasonably indicated to be within the invention. This rule applies with special force where the insertion is required by the Patent Office.

A patentee who acquiesces in the rejection of his claim and abandons it, based on references cited by the Patent Office, and accepts a patent on an amended claim, cannot maintain that the amended claim covers the combination shown in the references and that it is as broad as the abandoned claim. A patentee who does not abandon, but insists on and sustains his first claim, can later claim all of the benefits of his original specifications, in the courts, if necessary.

The insertion of new claims in a pending application is allowable, provided that general description is included in the original specifications and drawings.

Fraud

When a patent has been obtained by fraud, by mistake or by accident, the United States can bring proceedings against the patentee to have the patent declared void. The suit of the government, if successful, puts an end to all suits which the patentee can bring against anybody. In effect, it puts the patent at the disposal of the world.

In a suit for infringement of a patent, if the alleged infringer can prove that the patent was obtained through fraud, he will not be held liable for the infringement. Even if there is reasonable doubt as to the actions of the patentee, he will not be excused if he has not previously disclosed all information in his possession relative to the patent.

Surrendered Claims

When the patentee has by amendment cancelled or surrendered claims, the claims that are allowed cannot be worded to include the meaning of the abandoned claims. Also, a patentee cannot give to an allowed claim a scope which it might have had without the amendments. Although this rule is most frequently invoked when the cancelled claim is broader than that allowed, it applies also if the cancelled or rejected claim is narrower.

When a claimant has, under objection in the Patent Office, withdrawn certain claims, or has modified them by adding or striking out terms or phrases, and accepts a patent which does not grant the abandoned or unmodified claims, he cannot go to court for a "construction" of the allowed claims to cover what had been previously rejected and abandoned. These cases usually depend on matters of construction—the meaning of the patent. As in other cases of ambiguity, the application and file wrapper, and possibly written communications can be consulted. When the claims are not uncertain or ambiguous, the courts are reluctant to permit their interpretation of a patent to be affected by alleged conversations between Patent Office personnel and the claimant.

Building the full size apparatus is a critical phase in the patent process. Any deviation from the original drawings should be recorded, and the apparatus presented at the Patent Office. A full-scale model is also helpful in proving invention, in litigation.

Patent Office Delay

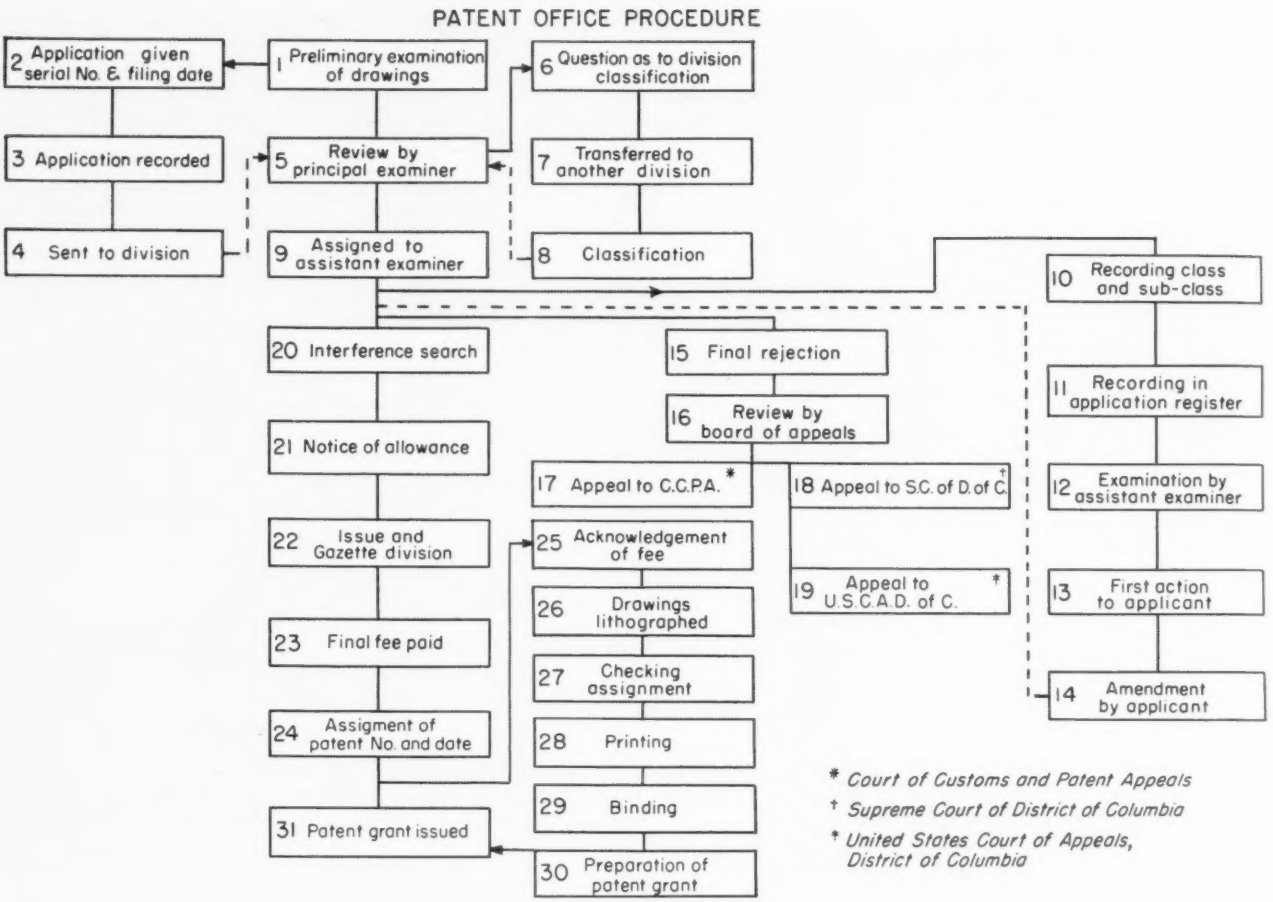
An applicant cannot be barred from making claims on his disclosure because of delay in prosecuting his application, if he has done all that is required of him by law and the rules of the Patent Office. However, if an applicant agrees to rejection of his application, or does not appeal, he cannot later revive his application.

Argument

An argument made before the Patent Office cannot control or restrict the language of the claims finally allowed. However, as a patentee cannot claim anything that the Patent Office rejects, the argument before the Patent Office can confirm that interpretation. Arguments of an attorney while the application is before the Patent Office have no effect on the scope of the claims.

Patent Office Actions

When the Patent Office finds a reference or previous patents which it considers to "anticipate" the invention, and the patent is later granted, such a patent is considered to be even stronger than an "uncontested" patent.


PATENT OFFICE PROCEDURE
2 Application given serial No. & filing date
1 Preliminary examination of drawings
6 Question as to division classification
3 Application recorded
5 Review by principal examiner
7 Transferred to another division
4 Sent to division
9 Assigned to assistant examiner
8 Classification
10 Recording class and sub-class
20 Interference search
15 Final rejection
11 Recording in application register
16 Review by board of appeals
21 Notice of allowance
17 Appeal to C.C.P.A. *
18 Appeal to S.C. of D. of C. †
12 Examination by assistant examiner
22 Issue and Gazette division
25 Acknowledgement of fee
19 Appeal to U.S.C.A.D. of C. ‡
13 First action to applicant
26 Drawings lithographed
23 Final fee paid
27 Checking assignment
14 Amendment by applicant
24 Assigment of patent No. and date
28 Printing
29 Binding
31 Patent grant issued
30 Preparation of patent grant
* Court of Customs and Patent Appeals
† Supreme Court of District of Columbia
‡ United States Court of Appeals, District of Columbia

The courts give the opinion that:

"The presumption of priority and novelty which arises from the granting of a patent must have greatly increased weight when the claim of the inventor is subjected to such close and careful scrutiny under the stimulus of a heated contest."

When is a Patent Office Action Due?

The Official Patent Office Gazette reports weekly the status of applications being prosecuted in each division. When the application is filed in the Patent Office, a filing receipt is issued indicating the division into which the application has been put for the purpose of examination. By referring to the weekly Patent Office list of work-load, a fairly accurate appraisal can be made of when the Patent Office action will be due. If it does not arrive on time, a letter should be sent to the Patent Office asking for a status report—it is the applicant's responsibility to get this from the Patent Office.

If the Patent Office mails the copy of the patent office action to the applicant and it fails to arrive, or even if the Patent Office clerks make a mistake and file the applicant's copy of the action in the official files, any default is charged against the applicant and he loses his application. This is an unjust rule, and an applicant should have his attorney check the patent status at frequent intervals.

The Patent Office examiner, after studying the patent application, seeks similar prior patents and publication. He writes the "action", rejecting claims which he believes are met by these patents and publications and points out why they are anticipated.

Sometimes, the chief draftsman of the Patent Office objects to the drawings. Written requirements are made for drawing corrections, which may be satisfied either by having the chief draftsman make the changes at the expense of the applicant, or new drawings are furnished by the applicant. The Patent Office examiner can also object to the form and content of the specification. He may object to the accuracy of the description or errors in numerals on the drawings and in the specifications. He can also find that the description indicates the invention is inoperative.

The primary object of the Patent Office is to prevent the allowance of claims whose terms attempt to monopolize that which is already old and public property, as shown by prior patents and publications.

The Patent Office can also indicate allowable claims, and can change its decision by withdrawing the allowance of such claims, at any time up to issuance of the patent.

Reply to Patent Office

The skill of the attorney is used to its fullest extent in the reply to the Patent Office. He must distinguish the prior patent and publications from the claims, or modify the claims to avoid infringing on the prior art; and argue why the changed claims are not met by the patent or publications.

The effort of the attorney is to get broad claims, while the effort of the Patent Office examiner is to prevent claims from being allowed at all, or if allowed, to keep them as narrow as possible.

Frequently, the question of operativeness, either of the invention covered by the application, or of prior art quoted by the examiner, arises. In such cases, affidavits and exhibits can be submitted to the Patent Office, or demonstrations made before the examiner and confirmed in writing, as

a part of the reply to the Patent Office. The inventor and his attorney can interview the examiner and verbally explain to him their position, confirming these statements in writing in the ultimate reply to the Patent Office. Such interviews prevent misunderstandings, and clarify the positions of the applicant and the Patent Office. But all of this must be confirmed in writing.

Requirements for Division

Frequently the Patent Office finds that there are two or more inventions disclosed and claimed. This may require the separation of such inventions into different applications. The applicant's attorney can ask that it be reviewed by the classifying examiner, whose decision is final, until appeal is taken. When divisional applications are filed, they have the benefit of the filing date of the original application.

Multiple Prosecution

Under present Patent Office practice, a single application can be considered by two or more divisions each of which will write a letter to the applicant, sending the letters of the several divisions together, so that the applicant can make a complete response. This prevents shifting of responsibility from division to division, and reduces the hazard of an invalid patent being issued.

Test of Invention

An application, even when found allowable, may be placed "in interference" with other applications. It is particularly important that manufacturers and inventors understand what such a procedure means. The interference procedure is a contest heard in the Patent Office to see who was first to make the invention. It then can be appealed to the courts.

The first to think of the invention, reduce it to some practical form and test it to show it is practical, is awarded the patent. Reduction to practice—the manner in which it is to function in use—is the actual test of the invention.

If a person is the first to think of an invention, but the last to reduce it to practical form, then the question is whether he was active and diligent in looking after his rights in a reasonable fashion, from the time his opponent came into the field until his own reduction to practice. If it is found that the inventor was neglectful and "slept" on his rights or that he practiced concealment and secrecy during this period, he can lose his rights even though he was first to think of the invention.

The purpose of this law is to encourage disclosure and filing of patent applications, that the public may have the benefit of them. Hence, one who conceals brings upon himself the suspicion that his experiments were abandoned, or that he did not have the invention at all. There are many other related and complicated rules, but this is the essential one.

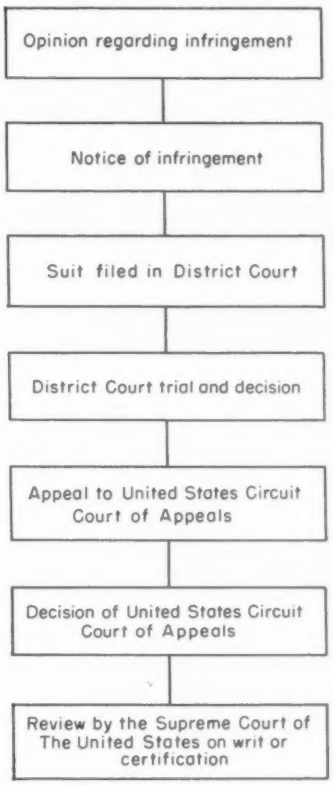
Reduction to practice or practical experiment can take the form of making the apparatus, testing it and showing that it is successful; or putting the invention in the form of a patent application and filing the application in the Patent Office. The latter is known as a "constructive" reduction to practice, and is the best evidence of good intent, in court action.

After a patent is issued, it frequently happens that, through some misunderstanding, it is necessary to have the patent reissued in a revised form to correct errors. This can be done any time within one year of the date of the issuance of the patent. The original drawings and disclosures must not be materially changed; only errors can be corrected, to make the document a perfect disclosure of the inventor's idea.

If, at any time the inventor discovers that he has mistakenly claimed portions of an invention to which he is not entitled, he can file a "disclaimer" on that portion of his patent, thus saving the rest of his patent, and preventing the whole patent from being defeated for lack of prior inventorship. The United States statute on disclaimers includes the following statement:

". . . .Such disclaimer shall be in writing, attested by one or more witnesses, and recorded in the Patent Office; and it shall thereafter be considered as part of the original specification to the extent of the interest possessed by the claimant and by those claiming under him after the record thereof. But no such disclaimer shall affect any action pending at the time of its being filed, except so far as may relate to the question of unreasonable neglect or delay in filing it."

INFRINGEMENT LITIGATION

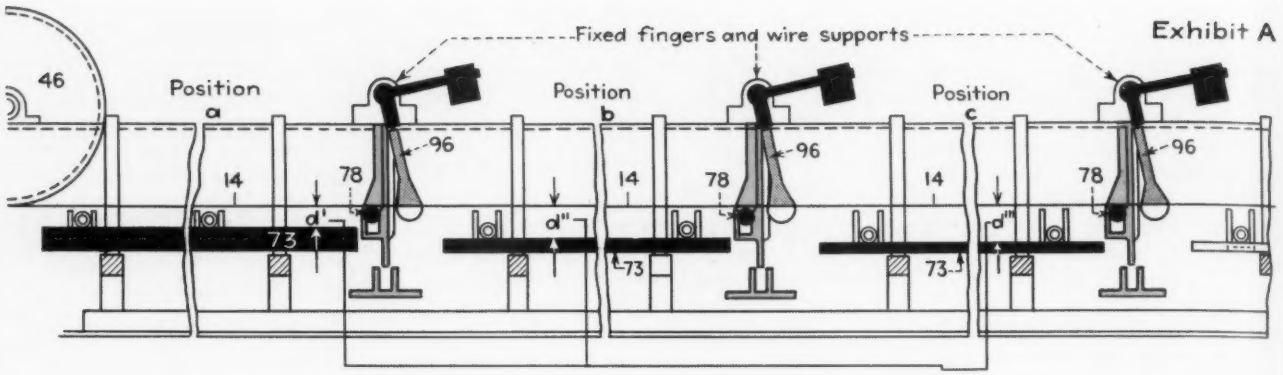

Opinion regarding infringement
Notice of infringement
Suit filed in District Court
District Court trial and decision
Appeal to United States Circuit Court of Appeals
Decision of United States Circuit Court of Appeals
Review by the Supreme Court of The United States on writ or certification

Infringement

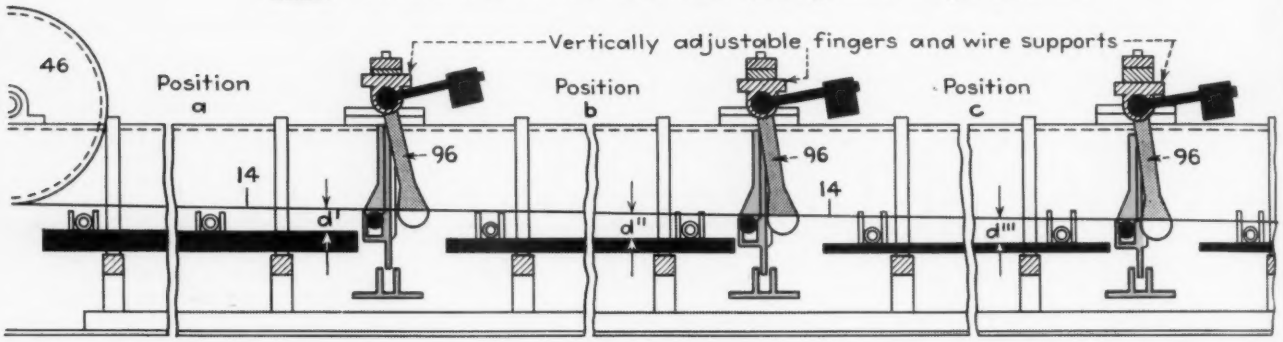
When the patent is issued, others, seeing the value of the invention, sometimes take the invention. This is patent infringement.

The patentee can bring suit for infringement against the offender in the United States courts. The questions before the court are: (1) Whether the defendant has taken the property of the plaintiff patentee, and (2) whether the patent of the plaintiff patentee is valid. Validity of the patent can be rebutted by the defendant introducing prior patents that were not discovered by the Patent Office. Even prior patents discovered in the Patent Office and whose full effect were not realized by Patent Office officials, may be used to defeat the patent. In this respect the court has a sort of reviewing power over the Patent Office. Prior publications can also be used to defeat the patent.

If the invention has been publicly made, used, or sold in the United States two years before the patent application was filed, or before the actual date of invention by the pat-



Note: Differences in inter-electrode spacings according to prior art



Note: Similar inter-electrode spacings according to appellant's invention

entee, then proof of such facts beyond reasonable doubt will cause the court to find that the patent is invalid. The court may find that part of the patent is valid and part invalid; and some of the claims may be infringed and some may not be infringed. Each claim stands on its own special merits and is separately treated.

Prior use of the invention in European countries does not defeat the patent. To defeat a patent, a foreign development must be in a publication or in a patent.

To avoid infringement the manufacturer should ask these questions, before capital is invested:

"Does this product, process, or design come within the boundaries of any patent we do not own? Will the machinery that we use infringe any patent? What steps shall we take to find this out?"

Infringement by intention can be avoided with a reasonable degree of certainty and ease. These are the steps that should be taken:

ALL UNEXPIRED UNITED STATES PATENTS IN THAT PARTICULAR FIELD SHOULD BE COMPARED WITH THE PROPOSED CONSTRUCTION OR PROCESS.

Earlier patents have broader claims, while subsequent developments, even though very important, can only be improvements on the original idea.

The original Wright patent on flying machines, for example, covered the invention of maintaining equilateral equilibrium of an airplane. That is, the patent covered any means of preventing the plane from turning over sideways, or tipping down on one side and going up on the other. It also covered the invention of steering the airplane in combination with this feature. The Wright patent shows plane surfaces which are warped at the corners or twisted in order to carry out this invention. Curtiss introduced ailerons—distinct, independent surfaces that were hinged to the main surface like shutters or doors.

The courts found that, regardless of the invention of ailerons, Curtiss was subject to the prior broad patent of the Wrights, covering any means of maintaining lateral equilibrium of airplanes.

EVEN WHEN INFRINGEMENT IS FOUND, WAYS CAN FREQUENTLY BE DEVISED TO REDESIGN THE STRUCTURE OR PROCESS.

A study of the prior patent art should reveal three important things:

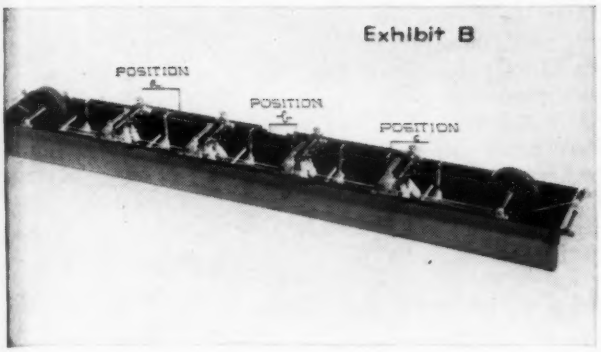
1. What is old and open to use as shown by expired patents?
2. What is new and covered by unexpired patents?
3. What developments or means of development have never been cultivated—what new fields are open for development in order that they can be monopolized?

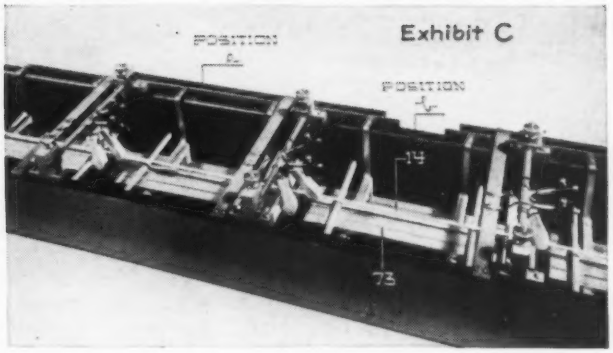
Aggregation or Combination?

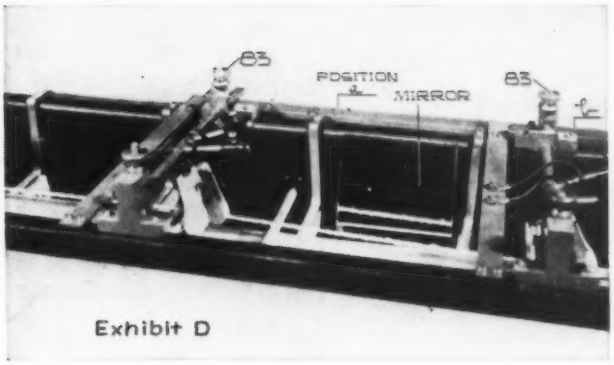
Many costly law suits have resulted because a designer did not know the legal distinction between an aggregation of elements or parts, which is not invention, and a combination, which is invention if it accomplishes something new and useful.

The Patent Office properly refuses a patent on a design that is merely an aggregation of parts. But the Patent Office sometimes mistakenly issues a patent on something "unpatentable". Later, the owner of the patent sues another for infringement, only to find that his "invention" is not valid and that his patent is void.

A patent was issued to cover a "combination" of elements for the automatic operation of a stoker. It included a stoker, a thermostat to control the stoker and a timing device to start the stoker, so that the fire would not go out for lack of fuel. Later, a competitor put on the market a similar group of devices to accomplish the same purpose. The patent owner sued on the grounds of infringement. He lost, the court holding that his







Importance of good diagrams and adequate photographs as proof of invention cannot be overemphasized. Sustained in litigation carried to the U. S. Supreme Court, this patent for a machine to make barbed wire, made J. W. Gates' American Steel and Wire Company an important factor in consolidation of steel companies which today constitute the U. S. Steel Corporation. Diagram and photographs of the machine and its operation, shown here, were vital parts of the evidence that led to granting of the patent.

patent was invalid. "The union," said the court, "is a mere aggregation unless the elements, by their united action, perform some function they do not separately discharge." The courts, perhaps unjustly, look upon aggregations as involving no creative intellectual achievement.

Typical of "mere" aggregations is a grease service tank, the patent on which was voided by the court. It included a series of pump or grease-gun supports; a corresponding series of pumps and grease guns; a series of indexes on the rack close to the supports, each mentioning a particular part of the automobile that needed specialized lubrication; a series of identification marks on the pumps; and a corresponding series of identification marks on the racks near the supports for identifying each pump with its support.

The court said about this: "There is no co-action between the support and the pumps, or between the pumps and the legend on the rack. It is the same as a carpenter's cabinet for augur bits, a druggist's cabinet or a hotel-keeper's rack for room keys . . . the old elements are brought together, not in the cooperative union of a true combination, but in the forced relationship of a mere aggregation.

Inventors frequently have the erroneous notion that simplicity or complexity is the test of aggregation or combination. One designer, for instance, worked out an apparatus for mixing and transporting concrete. It consisted of an upright chamber, in the top of which was an opening for introducing the material, equipped with a door to close the opening air-tight; a hopper-shaped bottom to the chamber, discharging into a delivery duct; a pipe through which compressed air entered the chamber above the mass of concrete to propel it into the duct; and another pipe delivering compressed air at or near the discharge or lower end of the hopper; and many other elements. However, it was not patentable because it was an aggregation of known devices, each acting in its regular way.

Producing an item that merely offers convenience and economy does not constitute invention. One often cited court ruling involved a washing machine and wringer geared together to permit simultaneous washing of one batch of laundry while the preceding batch is wrung out. The court ruled that no new function evolved from this combination.

A true combination can be extremely simple. The difference between aggregation and combination is illustrated in the grease-gun rack already described, which was an aggregation, and the metal filing cabinet invented by Rand, which was shown to be a true combination.

Merely because the elements are old is no bar to the patentability of a combination—provided that acting together they accomplish a new result that is more than the sum of their ordinary results. This is shown in a high-speed water turbine with adjustable runner blades to cooperate with the adjustable guide vanes. The fundamental object of the combination was to regulate the capacity of the turbine in accordance with the amount of power it is called upon to deliver, enabling the turbine to work at less than its maximum power with the use of a proportionate amount of water. Regulating devices used prior to this invention had the disadvantage of greatly reducing the efficiency of the unit when operating at less than full capacity.

Examples of unpatentable aggregations are a paste jar having one compartment for water and one for paste; a machine bringing together means for grouping, feeding, opening, moistening and sealing envelopes; two machines on a single bed-plate for performing succeeding operations on a product; and several tools on the turret of a turret lathe.

Form I — SUMMARY CARD

ORDER NO.....
Invention or Name of Machine

1. Conceived, date of..... by.....
2. Disclosed, dates of.....
3. " To (1)..... How disclosed.....
4. (2)..... " " .....
5. (3)..... " " .....
6. Sketches, dates of.....
7. Written Description, date of.....
8. Working Drawings (a) Started.....day of.....19..
9. (b) Completed.....day of.....19..
10. Started Full-Sized Machine.....day of.....19..
11. Completed Full-Sized Machine.....day of.....19..
12. Photographs of:
13. Start of Full-Sized Device, taken.....day of.....10..
14. Completion of Full-Sized Device, taken....day of....19..
15. Dates Tested:.....
16. Where Tested:.....
17. Result of Test:.....
18. Remarks:.....
19. .....
20. .....

Form II — PRELIMINARY SKETCH SHEET

Order No.....

1. Subject:
2.

3. Explanation:
.....
.....
.....
.....
.....
.....
4. Sketched by..... Date.....
5. Witnessed by..... Date.....
6. To Whom Explained Date
(a)

Form III — RESEARCH RECORD

ORDER NO.....

1. Object:
2. .....
3. .....
4. .....
5. Apparatus:
6. .....
7. .....
8. .....
9. Materials:
10. .....
11. .....
12. Method or Process:
13. .....
14. .....
15. .....
16. Result:
17. ..... Date.....
18. Experiment by: ..... Date.....
19. Witnessed By: ..... Date.....
20. Directed By: .....

Form IV — DRAWING FORM

1. Supersedes Drawing dated.....
2. Superseded by Drawing dated.....
3. Name of Job..... 15. Order No. .....
4. Part ..... 16. Shop No. .....
5. Tool ..... 17. Storeroom No. .....
6. Operation ..... 18. Planning Room No. .....
7. Drawn by.....12. Traced by ..... 19. Tracing Checked by.....Date....
8. Drawing Started.....13. Tracing Started..... 20. Tracing Approved by....Date....
9. Drawing Completed..14. Tracing Completed..21. Copies to:
10. Drawing Checked by..... Date .....
11. Drawing Approved by..... Date ..... 22. Sheet No.....

Records of the Invention Should be Kept

These include factory and laboratory records, preservation of original models, proof and identification of experimental machines, and such records which prove the existence of models or full-sized machines.

A manufacturer of trailers developed a novel trailer truck. He built it immediately and tested it extensively. He took no photographs of the truck. It was built up of parts around the factory, so that there were no drawings. After the tests he decided that he would defer building the apparatus until public taste caught up to the development. Meanwhile, his experimental department, needing the parts for another development, tore down the original truck.

Several years later, after filing a patent application, a Patent Office interference arose. There were no dated records, no drawings, no photographs, no purchase records of material that went into this particular truck—nothing that was definite except the testimony of witnesses, and that was verbal. Although the first to invent and the first to reduce to practice, he failed to make convincing proof to the Patent Office, and lost a very important invention. Thus, a million-dollar business was lost because management did not spend a few dollars on preserving records of the test.

Witnessed Test Runs

The best type of proof of an invention is to actually make the apparatus; or run tests showing what the inventive process is; or produce the product. When this is done, the tests should be witnessed by responsible people who later can testify as witnesses. Photographs should be taken with these persons included in the pictures, and the negatives should be dated the day they are taken. These negatives should be signed by the inventor and the witnesses. This makes a permanent record, and prints can be used as a basis of making disclosures within the organization and to outsiders. The records of the tests themselves should be carefully kept and dated and signed by those present, including the inventor.

The records covering the making of the test apparatus should also be kept apart from the general commercial records of the corporation, since it is the custom of many corporations to destroy records of this type after several years. All records concerning the invention, including the photographs, should carry the same serial number, which should be carried in a numbered record of inventions.

How to Prove the Date of Invention

Many patent cases have been lost because of inadequate proof of the date of invention. This is often caused by misunderstanding of the patent law covering the case. Inventors may think they have "taken steps" to prove the date of their invention, but they are often wrong.

One form of proof of date of invention, other than filing an application, is some written form of disclosure of the invention—drawings, dated photographs, and written and dated descriptions, signed by the inventor and several witnesses before a notary. This proof should then be mailed to an outsider who can be depended on to testify that he received the disclosure in the ordinary course of business.

Record forms such as these should be kept and used in every department of a manufacturing and research organization. Information should be given in as much detail as possible—a seemingly minor point can later make the differ-

Form V — MATERIAL PURCHASE RECORD

ORDER NO.....

Material	Order Number	Order Date	Invoice Number	Invoice Date	Voucher Number	Voucher Date
1. Steel						
2. Castings						
3. Patterns						
4. Brass						
5. Iron						
6. Aluminum						
7. Alloys						
8. Wire						
9. Chemicals						
10. Paper, etc., etc.						

A serious mistake made by many organizations is to have all the proof of the making of an invention and its disclosure limited to persons within the organization, witnessed only by employees and executives of the organization. In a patent office interference case, or in a question of prior use before a court, the other side can claim that the material has been specially fabricated for the occasion.

One of the effective ways to handle this is to provide regular disclosure booklets in which all inventive ideas of the research, engineering and development departments are recorded. These booklets are regularly mailed out from the organization with a statement of the nature of the invention, and whether or not it is to be protected by a patent application.

This proof should include drawings and sketches, dated and signed by the inventor and witnesses. The signatures should be in ink and, if possible, the drawings should be in ink. Either regular disclosure booklets, or a bound disclosure record book should be maintained for this purpose. Such disclosure records should be readily available in every laboratory, on each drafting table and in each experimental shop.

Record Forms

The fundamental purpose of all records of invention is to provide an unquestionable statement of exactly what occurred: Hence, any additional details are always welcome to make clear the record of the events.

Sound proof of this character will prevent litigation, and if litigation does become necessary, it makes success as certain as humanly possible. The accompanying illustrations show suggested patent record forms.

Inadequate Disclosure

The penalty for not making an adequate disclosure, corroborated by the testimony of someone outside of the inventor's own organization, is shown in the case of Bainbridge v. Walton. The Court of Customs and Patent Appeals affirmed the Board of Appeals of the Patent Office in awarding priority of invention to Walton on his invention relating to photoelectric tubes, because Bainbridge's evidence of record was insufficient to establish his reduction to practice earlier than Walton's.

Bainbridge introduced a 17-page exhibit consisting of data alleged to be based on tests conducted by him in September, 1928. There were no witnesses to the tests, although the immediate superior of Bainbridge testified that he knew in a general way of the work being done by Bainbridge, but had no recollection of having seen these data at the time.

Seven years later Bainbridge had his photoelectric tube tested in the presence of a physicist of the General Electric Company under conditions as close as possible to those existing when he made his 1928 tests, and sought by this method to prove what took place.

The court decided that: "The question presented, therefore, is whether the evidence of the tests made in July 1935 of (the) tube . . . . by appellant and the witness Koller may be considered as corroborative of appellant's testimony that he actually tested the tube in September 1938 and obtained from such tests the data disclosed. . . .

"Without intending to be understood as expressing any opinion as to whether such evidence could under any circumstances be considered corroborative in character, it is clear that it cannot be so considered here."

ence between a valid and invalid patent. Sketches and photographs, properly dated and signed, should be attached. If desired, a twelfth form—the patent litigation record—can also be used.

Form VI — CONSTRUCTION RECORD SHEET

ORDER NO. .....
Date

1. Started Preliminary Sketches .....
2. Completed Preliminary Sketches .....
3. Started Model .....
4. Completed Model .....
5. Working Drawings .....

	No. of Sheets	Date Started	Date Completed	Date Started	Date Completed
6.	1				
7.	2				
8.	3				
9.	4				
10.	5				
11.	6				
12.					
13.					
14.					
15.					
16.					
17.					
18.					
19.					
20.					
21.					
22.					
23.					
24.					
25.					
26.					
27.					
28.					
29.					
30.					

Form VII — TEST RECORD SHEET

ORDER NO. .....
Drawing No. ..... Date .....
Test Ticket No. .....

1. Description:
2. .....
3. .....
4. .....
5. .....
6. .....
7. .....
8. Ready for Test: Date .....
9. Hand Tested: Date .....
10. Result:
11. .....
12. .....
13. .....
14. .....
15. Power Tested: Date .....
16. Result:

Form VIII — STATEMENT BY WITNESS OF TEST

ORDER NO. .....

1. I, ... on the ..... day of .....,
2. 19....., first being duly sworn, state as follows:
3. I was a witness to a test of ..... on the ..... day of
4. ....., 19....., at ..... A.M./P.M. in the City of .....
5. County of ..... and State of .....
6. (a) .....
7. .....
8. .....
9. .....
10. .....
11. .....
12. .....
13. .....
14. .....
15. .....
16. State of }
17. County of } ss.

On the ..... day of ..... 19..... before

Form X — PATENT DEPARTMENT RECORD

1. Name of Inventor ..... Address of Inventor .....
2. Title of Invention .....
3. Received from Inventor ..... 19.... Execution .... 19....
4. Sent to Patent Office ..... 19.... Filed ..... 19.....
5. Serial No. ..... Preliminary Examination .....
Sheets of Drawings.
6. .....
7. Assignment of ..... interest to ..... Dated ..... 19....
8. Assignment forwarded ..... 19.... Assignment returned ..... 19.....
9. Recorded ..... 19..... Liber ..... Page .....
10. Delivered to Assignee ..... 19.....

..... Received ....., 19.....
..... Expire ..... 19.....
..... Forwarded .....
..... ived ..... 19.....
..... Office Receipt dated ..... 19.....

Form XI — FOLLOW-UP FORM

1	2	3	4	5	6	7	8	9
Order No.	Title	Conceived	Disclosed	First Sketch	Patent Application Started	Model	Drawings Started	Drawings Compl

10	11	12	13	14	15	16
Ordered Material	Patterns	Castings	Machining	Assembly	Test	Commer- duction

Form IX — PHOTOGRAPHIC RECORD FORM

ORDER NO. .....

1. Name of Device:
2. Who Took Photograph:
3. Place:
4. Date[c]:
5. Who Present:
6. .....
7. .....
8. .....

[a] Print on face of an envelope to carry negative and print.
[b] Put this number on a card on machine, etc., when being photographed.
[c] Put date of taking photograph on negative at the time of taking, if possible. An autographic kodak is of great value for placing the date on the negative.

Substitution of Materials

Many designers are under the impression that to substitute one material for another will entitle them to a patent. Usually, it will not; although under certain rare conditions a change of materials has been held to be patentable.

The field for achieving patentability, or avoiding infringement, by substituting one material for another is so narrow that most cases involving this question have been decided in the negative. The substitution of materials can constitute invention when:

1. It creates a new result not usually associated with the material.

2. It involves a new type of construction.

3. It enables new uses to be made of the device.

4. It makes an existing device successful for the first time.

In an electric make-and-break contact, tungsten was substituted for iridium platinum. It was regarded by the trade as cheaper and far superior to the old contact. The court held that it took more than uninventive substitution to make this change and that the invention was therefore patentable.

It was decided by another court that to substitute in a heating device a radiator of copper for one of cast iron or other heavy metal was not patentable, even though the copper radiator was more efficient. It was well known that copper is an efficient heat transmitter, and since there was no change in the function or effectiveness of the combination, there was no invention.

However, the court held valid a patent for a water cooler using a coil made of a resilient metal instead of a non-resilient lead or tin pipe. The problem had been to find a coil material which would not be damaged by falling pieces of ice. The substituted material performs a new function and its adaptability for the purpose was not evident, as shown by the fact that those familiar with the art had been striving for 50 years to find a way to protect the coils.

The substitution of metal parts for wood has many times been decided as unpatentable. It is held to be merely the use of reasonably good judgment to substitute a more rigid or durable material.

An important basic patent was that covering the substitution of tungsten as an electric light filament. The new material so greatly reduced the current consumption per candle power, as to practically revolutionize the electric light industry. It was not an obvious substitution. In fact the lamp manufacturers had been searching for years for better filament materials.

It was invention to substitute a known metal alloy in stated proportions for ineffective materials formerly used as resistance elements. The substitute material made commercially practicable the manufacture of a large line of electrical devices.

If the use of a substitute material results in a marked advance in the art it will usually be held to be a patentable invention. Thus Claude, by substituting neon for the more common gases such as nitrogen and carbon dioxide formerly used in the Moore tube, contributed greatly to commercial utilization of the light created in a gaseous discharge tube.

However, a court held that in making non-discolorable safety glass there was no invention in substituting for a certain type of plastic strengthening layer another kind of plastic previous used, where the advantage of the substitution is attributable to inherent physical properties.

A patentee sought to establish his right to a patent for a self-lubricating drier used in paper making machinery in the drying and bleaching of paper. The Patent Office had held that substituting a self-lubricating carbon or graphite packing ring for a steel or brass ring was not invention. But the court to which the case was taken felt that the substitution resulted in more efficient action, in lower cost of paper machines so equipped; and that explosions caused by excessive internal steam pressure in the old type of device were prevented. The patent was upheld.

One inventor substituted an aluminum alloy arm for a cast iron arm in clicking machines used in manufacturing shoe uppers. The court held that a new and useful result was obtained by this substitution because there was an increase in efficiency and a decided saving in operation costs.

The designer who is faced with the question of whether a substitution of materials will result in invention, or avoid infringement, can give it a preliminary test by using this statement of Mr. Justice Bradley of the Supreme Court of the United States:

"The use of one material instead of another in constructing a known machine is in most cases so obviously a matter of mere mechanical judgment and not of invention, that it cannot be called an invention unless some new and useful result, an increase of efficiency, or a decided saving in the operation is clearly attained."

"As a member of the patent board for several years, while the law authorized a board to grant or refuse patents, I saw with what slow progress a system of general rules could be matured. Some, however, were established by that board. One of these was, that a machine of which we were possessed might be applied by every man to any use of which it is susceptible, and that this right ought not to be taken from him and given to a monopolist, because the first perhaps had occasion so to apply it. Thus a screw for crushing plaster might be employed for crushing corncobs. And a chain-pump for raising water might be used for raising wheat; this being merely a change of material should not give title to a patent. As the making a ploughshare of cast rather than of wrought iron; a comb of iron instead of horn or of ivory, or the connecting of buckets by a band of leather rather than of hemp or iron. A third was that a mere change of form should give no right to a patent, as a high-quartered shoe instead of a low one; a round hat instead of a three-square; or a square bucket instead of a round one. But for this rule, all the changes of fashion in dress would have been under the tax of patentees."

—THOMAS JEFFERSON

Part II of this article, dealing with patent assignments and licenses, specific types of patents, and international patent problems, will be presented in the July issue of PRODUCT ENGINEERING.

5,000,000 Youngsters Need Our Help Now

THE bumper wartime crop of babies, about 5,000,000 larger than the population experts expected, is reaching school age.

At school these youngsters should find a good education awaiting them. That is their most cherished American birthright.

But unless something is done quickly, millions of these children will be cheated. They will crowd into classrooms already running on double shifts. They will move in with children who are now sitting two in a single seat. They will read germ-loaded books mangled by a generation of use by grimy hands.

I

So the continuing crisis in American education is given a new twist by unexpected pressure on school plant and equipment.

The U. S. birthrate has jumped by leaps and bounds. Instead of declining in the '40s, as the experts expected it would, the rate climbed from 17.9 per thousand in 1940 to 21.5 in 1943. It jumped to 25.9 in 1947, an increase of 45 percent since 1940. Result—by 1956 elementary school attendance in the United States is expected to jump from 18,200,000 to more than 23,400,000, an increase of about 5,200,000, or more than one-fourth.

The rush has already begun. It will pick up speed next fall.

Now, while this pressure has been building up, our public schools and their equipment have been running down—first through inevitable wartime neglect, then because inflation and material and labor shortages made it difficult to catch up.

If we are to give this bumper crop of youngsters the break they deserve—and reach the educational standards the nation needs—we must speedily do a major job of educational rehabilitation and expansion.

II

Some headway has been made in overcoming the teachers' salary crisis.

Teachers' salaries are improving. Pay problems were driving good teachers away from their posts in droves not long ago. But in the year since the 57th editorial in this series emphasized that crisis, the average teacher's annual salary has increased about $300—from $2250 to $2550.

True, increases vary enormously from state to state and from town to town. In a few states the average increase has been $500; in some less than $100. But, for the nation as a whole, last year's increase put teachers about even in the race with the cost of living. After taxes, their salaries have risen 68%, and the cost of living 67%, since 1939. In terms of pay increases, however, they are not nearly as well off as are industrial workers, whose average weekly wages after taxes have risen 108% since 1939. They are far behind farmers, whose net income is now four times what it was in 1939. And teachers had notoriously low salaries to start with.

A great deal more needs to be done in raising salary standards to put our school system on a firm footing. There are still about 100,000 teachers, nearly 12% of all public school teachers, who hold temporary or emergency credentials. They cannot meet

prevailing standards, and not very severe standards at that, for persons holding their posts.

The salary crisis, however, is easing.

III

But now comes the new crisis in school buildings and equipment.

We would have been hard put to get our schools back into shape after years of wartime neglect—even without a booming birthrate complicating the problem. Right now, 85% of all public school buildings need major remodeling to remove health and safety hazards.

And we aren't building enough new schools to keep up with current needs, to say nothing of catching up on those we were not able to build during the war years. School construction expenditures for 1948 are estimated at $375 million – which is less than what was spent in 1939. With building costs twice as high as they were in 1939, that means we aren't even holding our own—we are falling further behind.

And now comes the rush of war babies.

IV

We must spend at least $11 billion on new schools and equipment in the next decade.

Public and elementary schools must have $6.6 billion. Equally important, another $4.4 billion must be invested in buildings and equipment in our private schools, colleges and universities if they are to meet the demands which will be made upon them. The private school and the privately endowed university are doing their full share and doing it well. The need for them is increasing.

These figures cover only rockbottom needs for educational plant and equipment. But statistics are a very restricted recorder of this crisis.

You can see it better, I'm sure, in schools not very far from your home. There are schools with leaking roofs and outdoor toilets in our greatest cities. There are schools where students still use histories and geographies copyrighted before 1920—books with no mention of World War I, the depression of the 1930's, the Russian Revolution or the rise of the dictators. There are countless schools where modern methods of visual education are completely unknown.

All of these conditions promise to get worse – promptly – as that scheduled 5 million increase in the school population gets rolling.

V

The Metropolitan Life Insurance Company does not indulge in lurid prose. It says after painstaking study of the educational crisis that:

"Unless definite measures are taken immediately . . . large numbers of American boys and girls will be deprived of an adequate education."

Currently we are deeply concerned about our military defenses. We are taking, and I think rightly, emergency measures to strengthen them. But we must regard our schools as a part of our national defense as vital as are our armed forces. This is particularly true in these times of fifth columns and ideological warfare.

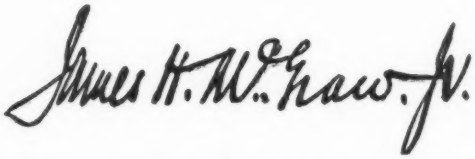
If we are wise, we will raise our sights. We will give the continuing crisis in education the same urgent attention being given the more obvious but no more real crisis in national defense.

Go to the school house in your neighborhood and discover what needs to be done to provide for the rising tide of young Americans. Ask your school board and your school administrators and teachers how you can help them.

That is good citizenship.

That is patriotism.

That is our duty to the oncoming generation.



President, McGraw-Hill Publishing Company, Inc.

THIS IS THE 68TH OF THE SERIES

Slip Rings and Brushes for Constant Electrical Resistance

Comparison of electrical contact resistance characteristics of 24 combinations of slip rings and brushes for transmitting low electric power such as required for resistance type strain gage.

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PRACTICALLY UNCHANGING contact resistance of slip ring and brushes for transmitting small amounts of power of the order required by strain gages can be obtained by using the right combination of materials for the slip rings and brushes. Although the tests to be discussed were for developing the most suitable slip rings and brushes for dynamic strain measurements using resistance-wire gages, the results provide a basis for predicting performance of other combinations for similar conditions.

The results of 24 combinations of materials for slip rings and brushes that were tested dry are shown in Table I. Test results of eight of the combinations operating in oil, thus simulating conditions such as when measuring crankshaft stress, are shown in Table II. Five of the combinations proved suitable for dry conditions. But the only combination that operated satisfactorily in oil was the shim-brass slip rings with Vickers hardness number of 150 and silver-graphite brushes with 175 psi brush pressure. All the dry combinations gave satisfactory wear, and the shim brass slip rings operated in oil from 5 to 10 hours without excessive wear. Test conditions for Tables I were: Wheatstone bridge circuit; gage resistance 1,000 ohms; gage strain sensitivity factor, 2.15; gage current 20-25 milliamperes; alternating stress at gage, 8,300 psi; slip ring speed, 2,370 rpm. Conditions were the same for Table II except that a 500 ohm gage was used.

When using resistance-wire strain to measure dynamic strains, some type of sliding contact such as slip rings and brushes usually connect the strain gages to the indicating instruments. The considerable research on sliding contacts for transmitting power in motors and generators is of little practical

Table I—Comparison of Slip Ring and Brush Materials Tested Dry

Slip Ring		Brush Material	Result	
Material	Vickers Hardness No.		Performance	Brush Pressure, psi
Plate brass	116	Silver graphite*	Good	90 required
Plate brass	116	Copper graphite**	Good	125 required
Plate brass	116	Magnesium alloy	Poor	At 12, excessive wear of rings
Plate brass	116	Aluminum	Poor	At 12, excessive wear of rings
Plate brass	116	Soft carbon	Poor	At 175, unstable operation
Plate brass, shotblasted	161	Silver graphite*	Good	80 required
Shim brass	139	Copper graphite**	Good	150 required
Shim brass	139	Soft carbon	Good	175 required
Shim brass	139	Hard carbon	Good	150 required
Shim brass	150	Silver graphite*	Good	95 required
Silver plated	—	Silver graphite*	Poor	At 80, unstable and slight wear of rings
Silver plated	—	Copper graphite**	Poor	At 40, slight wear of rings
Silver plated	—	Soft carbon	Good	95 required
Silver plated	—	Hard carbon	Good	95 required
Monel metal	124	Silver graphite*	Good	95 required
Monel metal	124	Copper graphite**	Good	125 required
Monel metal	124	Hard carbon	Good	225 required
Inconel	181	Silver graphite*	Good	100 required
Inconel	181	Copper graphite**	Good	125 required
Inconel	181	Soft carbon	Good	200 required
Stainless steel	185	Silver graphite*	Good	100 required
Stainless steel	185	Copper graphite**	Poor	At 100, unstable and slight wear of rings
Stainless	—	Soft carbon	Poor	Up to 250, unstable operation
Carbon steel, hardened	602	Magnesium alloy	Poor	At 12, unstable operation and excessive wear

Table II—Slip Ring and Brush Materials Tested in Oil

Slip Ring		Brush Material	Result	
Material	Vickers Hardness No.		Performance	Brush Pressure, psi
Plate brass	116	Silver graphite*	Poor	At 185 slip rings worn excessively
Shim brass	150	Silver graphite*	Good	175 required
Silver plated	—	Silver graphite	Poor	At 12, slip rings worn excessively
Silver plated	—	Copper graphite**	Poor	At 60, slip rings worn excessively
Silver plated	—	Hard carbon	Poor	At 60, slip rings worn excessively
Silver plated	—	Soft carbon	Poor	At 60, slip rings worn excessively
Monel metal	124	Silver graphite*	Poor	Up to 400, unstable operation.
Inconel	181	Silver graphite*	Poor	Up to 400, unstable operation.

* 60 percent silver by volume ** 50 percent copper by volume

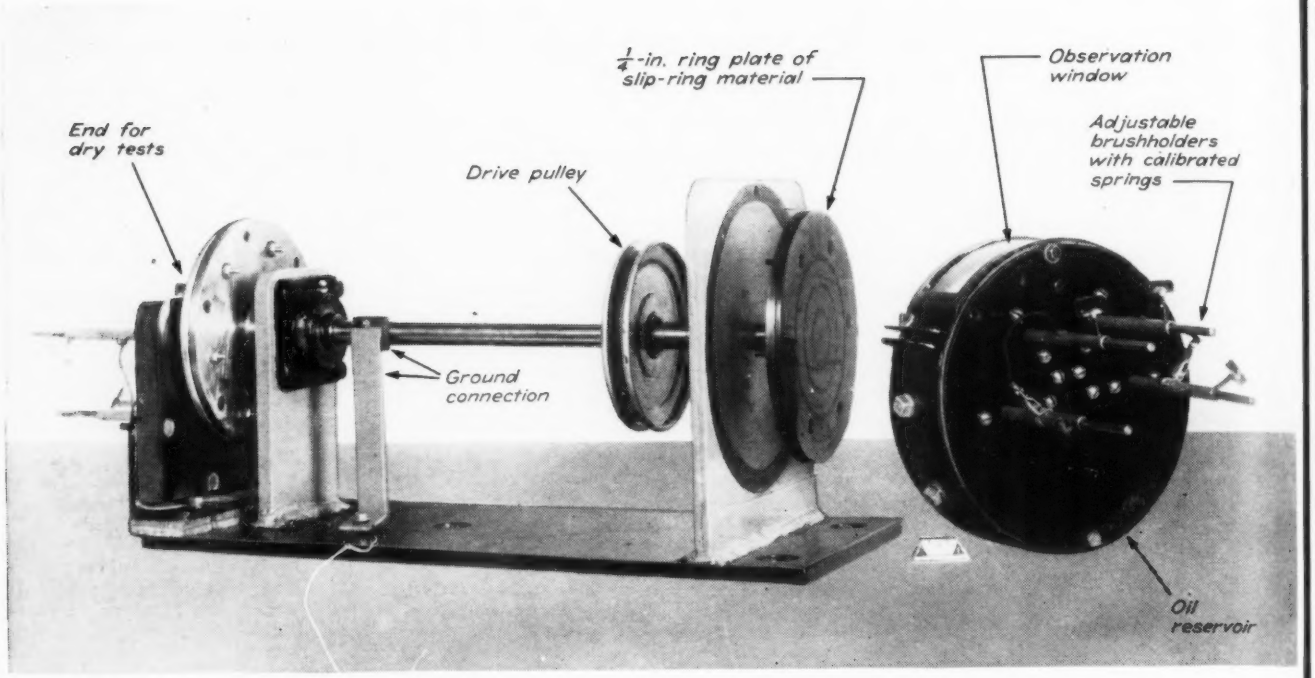


Fig. 1—Machine for testing slip rings and brushes for use in dynamic strain measuring applications. Slip rings can be bolted to face plates on either end of the shaft. Ring plate at right hand end of shaft dips into an oil bath in the bottom of housing.

value, because slip rings and brushes in electric machinery are designed essentially for low voltage drop and variations in the drop are unimportant. Slip-ring systems for measuring dynamic strains can have an appreciable voltage drop as long as the drop for a given current remains constant within close limits.

Test Setup

Combinations of slip-ring and brush materials both dry and wet with oil and at various slip-ring speeds and brush pressures were tested by the machine shown in Fig. 1. All the slip rings tested were of the axial type; that is, the sliding-contact surfaces were perpendicular to the slip-ring axes of rotation.

Two different types of construction were used on the slip rings. In one type of assembly, the slip rings were made of shim brass, 0.016 in. thick and $\frac{3}{8}$ in. wide, with mean diameters of $1\frac{1}{2}$, 3, $4\frac{1}{2}$, and 6 inches. A phenolic resin cemented these four thin rings to a steel disk $\frac{1}{4}$ in. thick and 7 in. in diameter. The second type of construction used slip rings that were disks $\frac{1}{4}$ in. thick and 7 in. in diameter made of the slip-ring materials being tested. These slip rings, or "ring plates", were bolted to face plates on either end of the shaft of the testing machine as shown in Fig. 1. The ring plate on one end of the shaft of the testing machine was housed for operation of the slip rings in oil. As the ring plate rotated, it dipped into an oil bath in the bottom of the housing and splashed oil on the slip rings. An adjustable speed drive rotated the slip rings at speeds from 500 to 3,000 rpm.

The brushes were $\frac{1}{8}$ in. in dia and $\frac{9}{16}$ in. in length and their longitudinal axes were parallel to the axis of slip-ring rotation. Calibrated springs in adjustable brush holders provided brush pressures from 12 to 400 psi; brushes could be operated on any one of four slip rings.

Signals of different amplitudes were generated by resistance-wire strain gages of 500 and 1,000 ohm resistance with a strain-sensitivity factor of approximately 2.15. The strain gages were mounted on a steel cantilever beam and subjected to a bending stress at frequency of 1,000 cycles per min thus generating essentially a sine wave. The stress ranges applied to the 500 ohm and the 1,000 ohm gages were 12,000 and 8,300 psi respectively.

By a selector switch either the Wheatstone-bridge circuit or the potentiometer circuit shown in Fig. 2 could be used.

Wheatstone-bridge Circuit. The slip rings and brushes at the ends of the testing machine shaft could be placed in series with the battery circuit or shorted out of the battery circuit. In a dynamic-strain measuring application, with the arms of the bridge attached to the rotating part under test, slip rings and brushes are used in the amplifier-oscilloscope circuit in addition to those in the battery circuit. But in these tests it was unnecessary to test the sliding contacts in the amplifier-oscilloscope circuit because the varying contact resistance of the slip rings and brushes is negligible as compared with the 500,000 ohm total impedance of the amplifier-oscilloscope circuit.

The amplifier-oscilloscope circuit of a Wheatstone bridge is affected by slip-ring and brush interference even when the bridge is in resistance balance. This interference is caused by the effect of the rapidly changing voltages and currents applied by the slip rings and brushes and is a function of all the capacitances, inductances, and resistances in the entire circuit. The bridge could be balanced for one frequency so that a sinusoidal change of resistance in the battery circuit would not affect the oscilloscope. But because the interference includes a wide band of frequencies a condition was never found that would eliminate the slip-ring and brush interference. Filters to improve the system were not used in this investigation because they would have partly obscured the comparison of performance between the different types of slip ring. A filter in the amplifier-oscilloscope circuit would eliminate components of the strain signal as well as the interference introduced by the slip rings and brushes.

Potentiometer Circuit. The slip rings and brushes at the ends of the

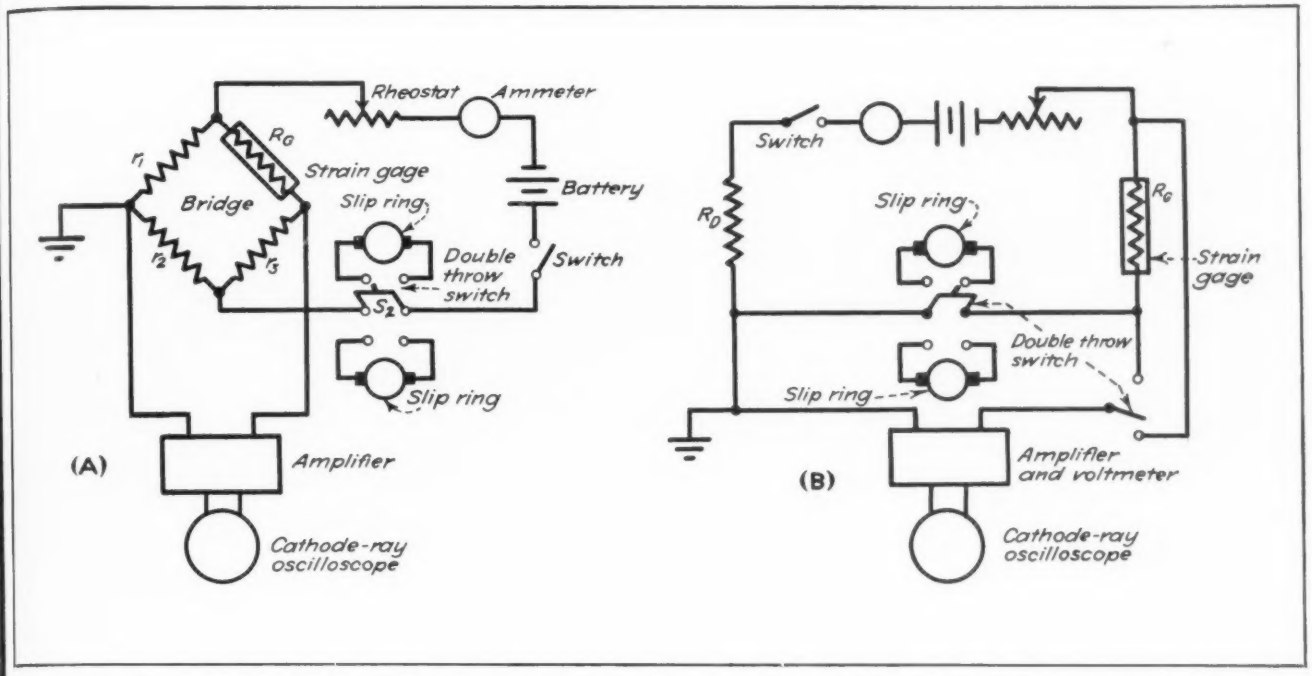


Fig. 2—Circuits for testing slip ring and brush combinations to determine satisfactory pressure. (A) In Wheatstone bridge, circuit, resistances r_1, r_2, r_3 and R_G are approximately equal. (B) In potentiometer circuit, resistances R_D and R_G are approximately equal.

testing-machine shaft could be either placed in series with the battery and the strain gage or shorted out of the circuit. A combination electronic voltmeter and amplifier was used to calibrate the cathode-ray oscilloscope. It also amplified the strain-gage signals or the signals generated by the varying voltage drop across the sliding contacts.

In the potentiometer circuit, a change in resistance through the sliding contacts had exactly the same effect on the recording instruments as a similar change in resistance of the strain gage. For this reason, recording instruments in the potentiometer circuit were more sensitive to changes in the sliding-contact resistance than recording instruments in the Wheatstone-bridge circuit.

Minimum Brush Pressure

On the basis of minimum brush pressure, satisfactory performance was defined as the condition of operation in which no difference is apparent between the signals when the slip rings and brushes were in the circuit and when they were shorted out of the circuit.

Four brushes on the same slip-ring diameter were placed in the battery circuit of the Wheatstone bridge shown in Fig. 2(A). Two of the brushes connected in parallel conducted the current into the slip rings and two of the brushes connected in parallel conducted the current out of the slip rings. The signal was generated by a strain gage of 1,000 ohm resistance mounted on the steel cantilever beam at a point where the maximum alternating stress was 8,300 psi. and the strain-gage current was maintained between 20 and 25 milliamperes.

Test Procedure

At the beginning of a test the slip rings and brushes were cleaned with acetone and their mating surfaces were polished. The setup was then given a 1 hour run-in with the slip rings rotating at 1,000 rpm and the brush pressure at approximately 60 percent of that required for satisfactory operation. This run-in period allowed the film conditions of the brushes and slip rings to approach equilibrium.

Following the run-in period, the brush pressure was reduced to 12 psi, the slip-ring speed was increased to 2,370 rpm, and the slip ring was run for 15 min. If at the end of that time the trace observed on the oscilloscope screen was unsatisfactory, the brush pressure was increased and the slip ring was run for another 15 min. Thus, while the slip ring speed remained constant, the brush pressure was increased until a point was reached at which the trace was satisfactory. The oil used in the tests was SAE 60, and a temperature of approximately 150 F was maintained. Five of the combinations listed in Table I were considered more practicable for use in circuits to measure dynamic strain. These were tested to determine minimum brush pressure for satisfactory operation at different speeds.

Contact-Resistance Change

For the preferred combinations, the slip ring and brush contact resistance change also was measured in the following manner. The oscilloscope was calibrated in the potentiometer circuit, Fig. 2 (B), by connecting the electronic voltmeter across an operating strain gage and adjusting the strain-gage current until the signal amplitude was equal to 0.00265 volt (rms), as indicated by the voltmeter. With the signal amplitude set at this value, the voltmeter was used as an amplifier and its output connected to the oscilloscope. The total signal amplitude as viewed on the oscilloscope screen was equal to

$$\frac{0.00265 \times 2}{0.707} = 0.0075 \text{ volt}$$

The amplifier-gain controls were so adjusted that the total signal amplitude was equal to $\frac{1}{2}$ inch, thus fixing the calibration at 0.015 volt per inch.

To determine the contact-resistance change, the signal generator was disconnected and the amplifier and the oscilloscope were connected across the operating slip rings and brushes. By means of the calibration, the magnitude of the varying voltage drop through the slip rings and brushes was measured on the oscilloscope screen. The high-frequency contact-resistance change $\triangle R$ was calculated by substi-

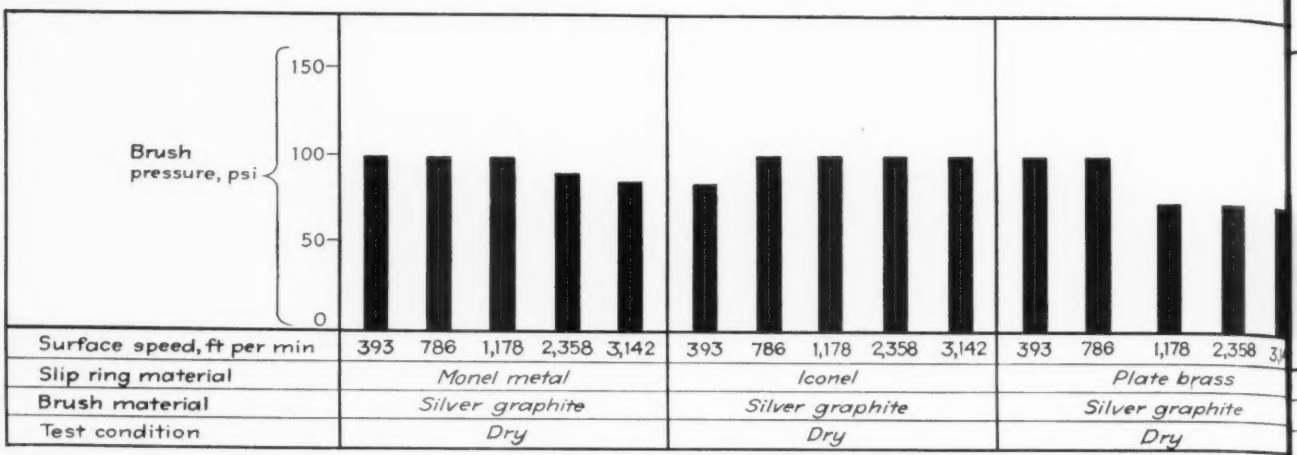


Fig 3—Minimum brush pressure required for satisfactory performance. Test conditions Wheatstone bridge circuit; alternating stress at gage, 12,000 psi; gage characteristics were

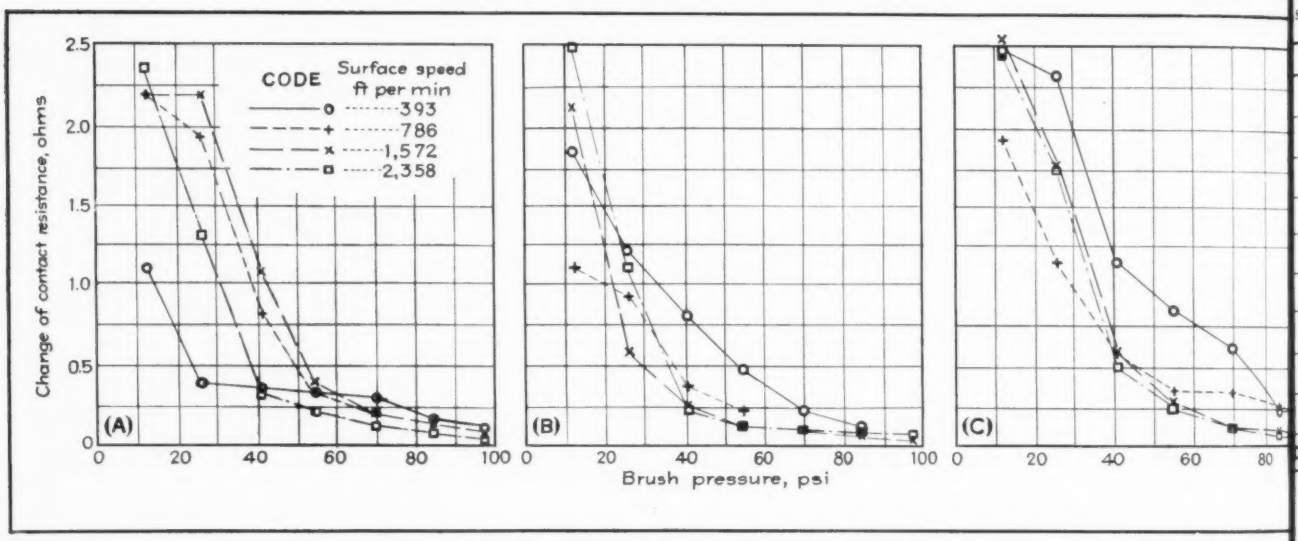


Fig. 4—Effect of brush pressure at different surface speeds on contact-resistance change on dry tested combinations of slip rings and brushes, respectively: (A) Plate brass and

tuting the measured values for the current I and the voltage drop ΔV in the equation:

$$\Delta R = \frac{\Delta V}{I}$$

Wear Tests in Oil

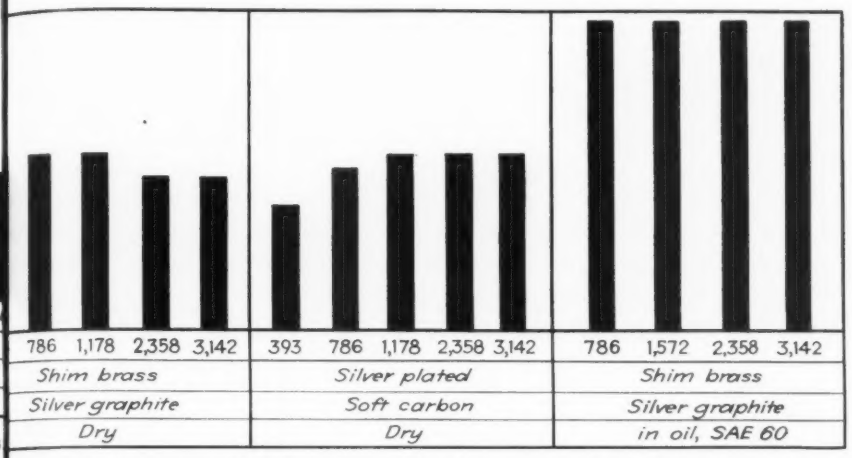
Wear tests were run on shim-brass slip rings and silver-graphite brushes operating in oil because of the extremely high brush pressures required for satisfactory performance. The slip rings and brushes were cleaned in acetone, the brush pressures were set sufficiently high, ranging from 150 to 250 psi., to give satisfactory operation, and the slip-ring speed was set at 2,370 rpm. During the 6 to 10 hour test, the slip rings ran continuously except for inspections at regular intervals.

Slip Rings and Brushes Dry

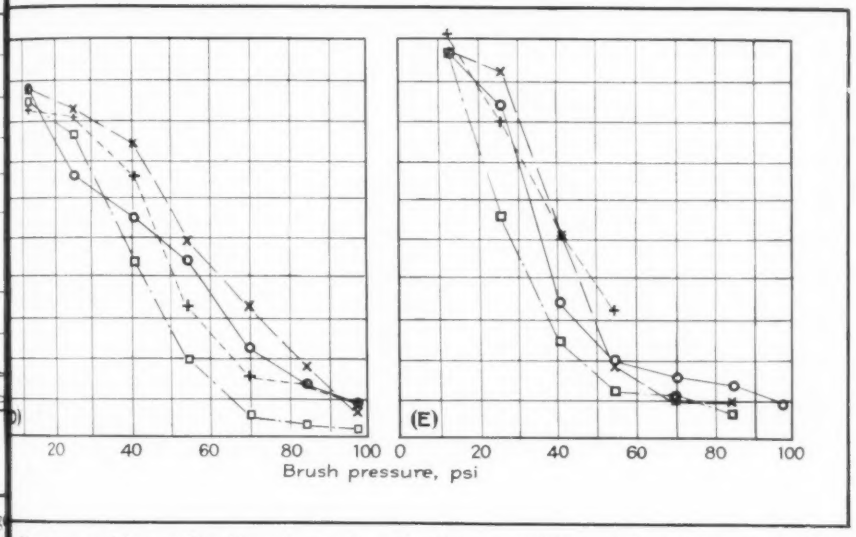
Many of the dry tested combinations in Table I were satisfactory in performance but the five combinations considered most practicable for use in circuits to measure dynamic strain are: (1) Plate-brass slip rings and silver-graphite brushes, (2) Monel-metal slip rings and silver-graphite brushes, (3) Inconel slip rings and silver-graphite brushes, (4) shim-brass slip rings and silver-graphite brushes and, (5) silverplated slip rings and soft-carbon brushes The minimum brush pressures required for satisfactory operation of the foregoing combinations are given in Fig. 3. The remarks on performance in Table I and the data in Fig. 3 apply to the Wheatstone-bridge circuit. Data in Fig. 3 are in terms of ft per min surface speed because slip rings of four diameters were tested at different speeds.

When applying these results to similar slip-ring and brush systems, the effect of certain factors on the strain-gage signal must be considered. The magnitude of the strain-gage signal is dependent on the gage current, the gage resistance, the gage strain-sensitivity factor, and the amount of strain at the point where the gage is mounted. The values that were assigned to each of these factors for use in this investigation were arbitrary and are not necessarily the same as will be used in other dynamic-strain applications. It should be noted that the ratio of slip-ring and brush interference to strain-gage signal varies inversely as the gage resistance, the gage strain-sensitivity factor, and the range of strain at the point where the gage is mounted. This same ratio is unaffected by changes in gage current. Thus, an improvement in the performance of a slip-ring and brush system can be effected by increasing the gage resistance, the sensitivity factor of the strain gages, or the range of strain.

The data for different surface speeds in Fig. 4 shows a decrease in the change of high-frequency contact-resistance as the brush pressure is increased. It is apparent from the trend of the data that the brush pressure is critical and that to decrease it much below the minimum values shown in



2.15 sensitivity factor, 500 ohms, 35 to 40 milliamperes. In applying these data to systems, the effect of certain factors on the signal must be considered.



silver graphite; (B) Monel metal and silver graphite; (C) Inconel and silver graphite; (D) Shim brass and silver graphite; and (E) Silver plated and soft carbon.

Fig. 3 would greatly increase the amount of interference in the signal.

It is possible to determine the performance of a potentiometer circuit from the contact-resistance change of the slip rings and brushes because the strain gage and the sliding contacts are in series in the potentiometer circuit. The strain-gage signal and the slip-ring and brush interference are directly proportional to the resistance change of the strain gage and the resistance change of the sliding contacts. With a 500 ohm strain gage mounted on steel subjected to a stress of 10,000 psi, the resistance change of the strain gage is 0.358 ohm. From the data in Fig. 4(*A*) it can be seen that the lowest value of contact-resistance change is 0.031 ohm. Thus, for the operating conditions given in Fig. 4(*A*) the minimum ratio of interference to strain-gage signal would be:

$$\frac{0.031}{0.358} = 0.086$$

This ratio, or interference factor, can then be used as a measure of the performance of the circuit; the lower the interference factor the better the performance obtained from the system.

Surface Oxides

There is evidence that films such as oxides form on the surface of slip rings. These films are seldom continuous and therefore they contribute to changes of the contact resistance. The brushes scrape a part or all of this film from the slip rings, depending on the brush pressure, and thus at the higher brush pressures most of the film is removed and the contact-resistance change is lowered. The tendency of films to form more easily on some surfaces than on others is one of the factors that distinguish a poor slip ring from a good one.

The wear-resistant characteristics of these combinations were excellent at all the brush pressures used during the tests. But the total running time on any combination did not exceed 6 hours; it was estimated that this amount of time would be sufficient to obtain dynamic-strain data from an operating machine part. A shim-brass slip ring and silver-graphite brush combination operated satisfactorily without excessive wear on a crankshaft and connecting-rod strain-measuring application for 22 hours.

Slip Rings and Brushes in Oil

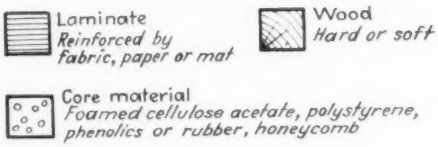
The most significant fact from the tests run in oil was the extremely high brush pressure required for satisfactory operation, as shown in Table II and Fig. 3. Only the shim-brass slip rings and the silver-graphite brushes were satisfactory under these conditions. The high brush pressures used in these tests apparently eliminated the trends observed in Fig. 4 for dry operation. In all the tests on the shim-brass slip rings and silver-graphite brushes run in oil, the contact-resistance change remained at an undetermined high value until a brush pressure was reached at which the resistance change fell off abruptly to a small negligible quantity.

The difference between operation dry and wet is caused by the oil film on the slip rings. This oil film remained on the contact surface between the brushes and slip rings until the brush pressure was sufficiently high to break it down. The breakdown of this film was for all practical purposes, instantaneous, after which the brushes made positive electrical contact with the slip rings and the contact resistance became negligible.

The wear-resistant characteristics of the materials involved in operation in oil are extremely important because of the high brush pressure required to break down the lubricating oil film at the points of sliding contact. Tests conducted on slip rings at brush pressures of 200 psi and speeds of 2,370 revolutions per minute indicated that the slip rings could be operated for 10 hr without undue wear.

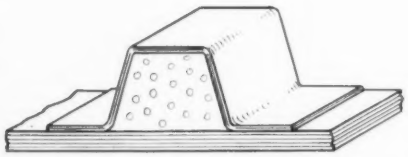
One of these shim-brass slip-ring systems was also installed on an engine-crankshaft and connecting-rod stress-measurement setup where it operated for 5 hours before the wear became excessive It was found that, if these slip rings had a Vickers hardness number of less than 150 or if the brushes became chipped at their contact surfaces, prohibitive wear might take place in as short a time as 30 minutes. In an effort to eliminate chipped brushes as a cause of wear, the contact surfaces of the brushes and slip rings were polished and the edges of the brushes were rounded to a $\frac{1}{64}$ in. radius.

Characteristics and Configuration of

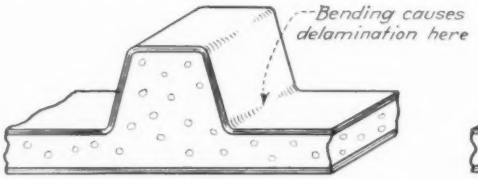


Reinforced plastic moduli of elasticity are lower than for most metals and consequently allow greater elongation when stressed. When materials with different moduli are bonded together, special conditions are produced by stressing the adhesive in shear. These conditions can some

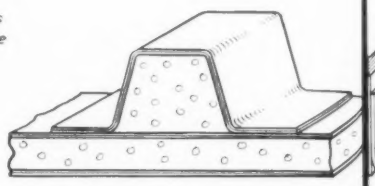
RIBBING STRUCTURAL PLASTIC PARTS



RIBBED LAMINATE. When reinforced plastic parts are not sufficiently stiff (because of a thin section or because of a flat shape), ribs can be added to prevent collapse. The ribs can be of various cross sections, but this one is simple and efficient.

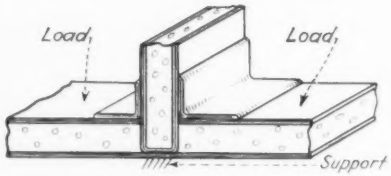


RIBBED SANDWICH. Generally sandwich structures are sufficiently stiff in themselves, and ribs may weaken sandwich panels by shifting the neutral axis. Ribs may provide bosses for further assembly; bulkheads can be attached to ribs in the hull of a boat.

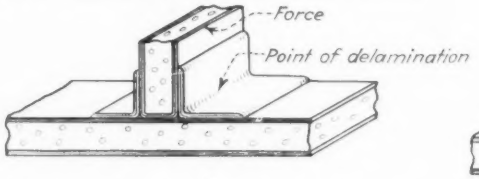


RIBBED SANDWICH, Preferred Design. For the same reasons applicable to the previous joint, this one can introduce no weakness. Fabrication requires minimal material and time, but the continuation of the upper skin on the horizontal panel adds greatly to the strength.

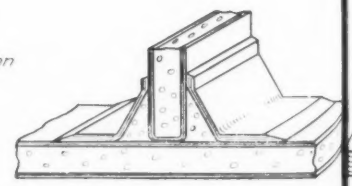
NINETY DEGREE JOINTS IN SANDWICH



INSET RIGHT ANGLE JOINT. This joint weakens the panel by interrupting the skin on the upper surface of the horizontal panel. This joint makes a particularly weak assembly when loads are applied on ends of the horizontal panel as it is supported under the vertical.

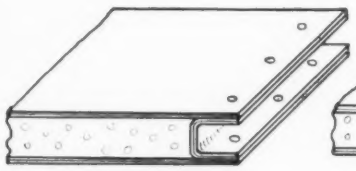


SURFACE RIGHT ANGLE. Sandwich panels joined in this manner do not have the same weakness exhibited by the previous joint. The horizontal panel is not disturbed and retains its full strength. Excessive horizontal forces normal to vertical panel can cause delamination.

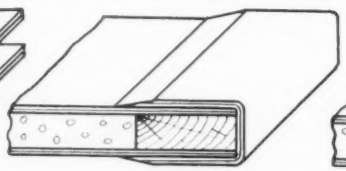


RIGHT ANGLE WITH GUSSETS. This type of joint retains intact the surface skin for both panels and, because of the angle of additional support, this type joint can more easily resist side loading. The joint is not difficult to produce and gives most strength for its type.

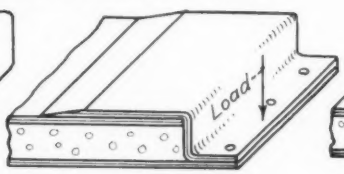
TYPICAL EDGE TREATMENTS FOR SANDWICH



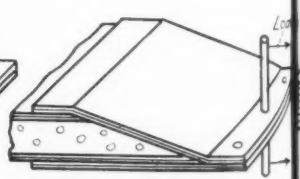
TONGUE AND GROOVE ASSEMBLY. This joint permits tongue and groove assembly for large areas where flush joints are required. The joint is simply made and is strong. The final edge of the last panel can be finished off with any of the next three joints.



HIGH DENSITY INSERT EDGE. Any high density material can be used as the edge insert for this joint. When wood is used, further assembly can be done by screwing through the laminate and anchoring in the wood. The channel section can be made of light metal.



FLANGE EDGE. Here the two skins of the sandwich have been tied together and a flange provided. This construction has been used for doors in aircraft. This type of edge is particularly useful when it is loaded as shown on the sketch.



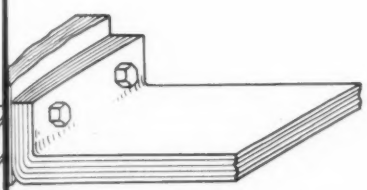
WEDGE-SHAPED EDGE. This wedge-shaped edge provides a very strong joint where the loading is to be along the plane of the panel. General lap areas are provided where it is necessary to transmit large tensile loads to the skins of the sandwich.

f Reinforced Plastic Joints—II

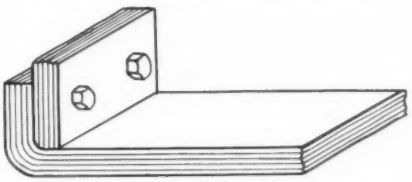
nes be counteracted by bonding laminates of different thicknesses; ng thicker section for lower modulus material. Below are shown 20 nts used in assembling reinforced plastics that are illustrated with same cknesses for parts made of materials with identical moduli of elasticity.

RICHARD J. FRANCIS
Consulting Engineer

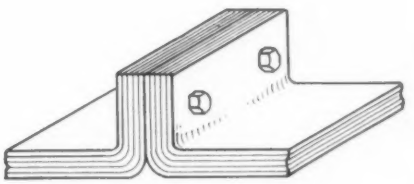
BOLTED AND RIVETED JOINTS



TSIDE CORNER. The outside corner t is stronger than the corner butt (see Part I) because of the addi- nal bonding surface, but it also is s against bending stresses. It is par- larly good for horizontal compres- loads.

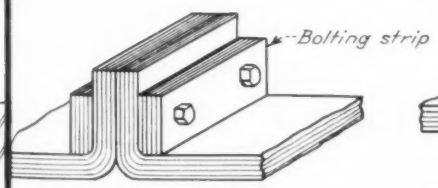


INSIDE CORNER. This joint is good for carrying horizontal tensile loads. When bonding supplements bolting, the bolts provide clamping pressure as the adhesive sets. Also, the excess adhesive fills the voids in the bolt holes, thereby improving bearing characteristics.

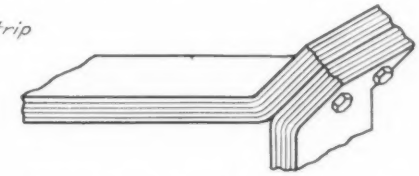


NINETY DEGREE FLANGE. Tensile loads on horizontal laminates of this joint would cause peeling because the load is applied eccentric to the bolts. This same loading tends to produce bending at the angle and may result in delamination if the load is excessive.

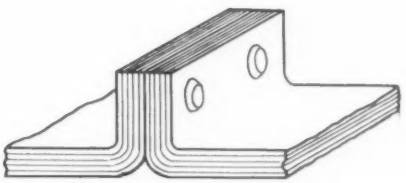
BOLTED AND RIVETED JOINTS



NETY DEGREE FLANGE WITH STRIPS. th the delamination and the peeling dencies of the plain ninety degree ge joint can be avoided by adding ting strips on both sides of the joint. the bolting strips are bonded to the inates, a very strong joint is formed.

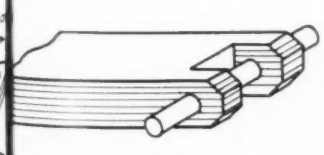


FOURTY-FIVE DEGREE FLANGE. The fourty-five degree outside flange and the two ninety degree flanged joints are excellent for shipping parts in knocked-down condition. The joints are simply made and can be formed at the final point with no trouble.

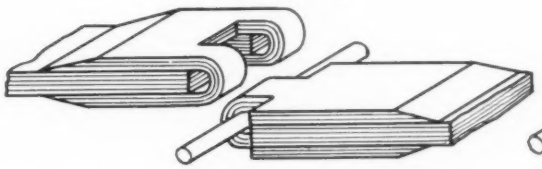


RIVETED JOINTS. Rivets are sometimes used where the fastening is to be permanent. The rivets used on sheet metal are satisfactory. Riveting is the same except that when expanding rivets are used, care is taken to prevent damage to the laminating resin.

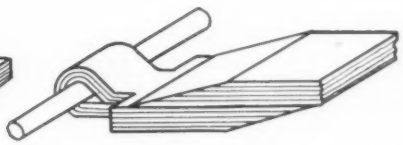
HINGE JOINTS



LLED HINGE. Drilling the e of a laminate and insert- a rod makes a simple ge joint. High tensile sses point to the two in- ent weaknesses: reduction cross section and low re- ance to shear stresses in the e of the laminations.



DOUBLE STRAP HINGE. The components of a piano type hinge are shown in an exploded position. Looping the reinforcement around the rod and adhering to both sides of the laminate makes an unusually strong joint. Where strength is the only consideration, the rod may be metal, but where electrical characteristics are a factor, the rod may be of the same reinforced plastic.



SINGLE STRAP HINGE. Where only one side of the laminate is accessible, reinforcement, looped around the rod, can be bonded to one side. Some eccentricity may be developed in this design. Edges of laminate and strap are bevelled to reduce peeling.

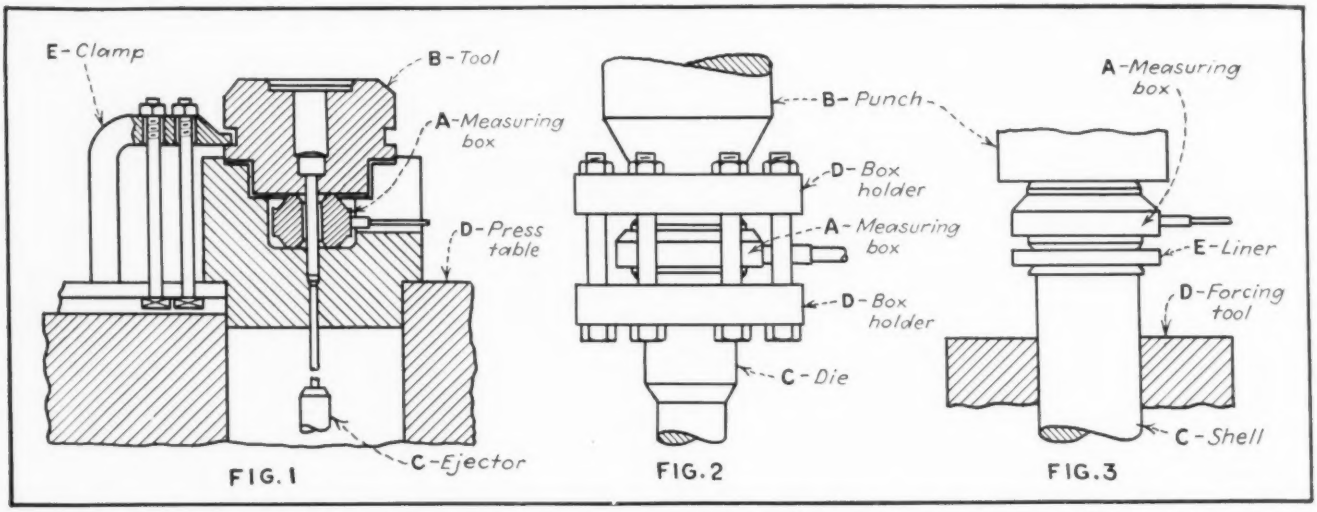


Fig. 1—Measuring box placed beneath the tool. Fig. 2—Between punch and die. Fig. 3—Freely supported by the shell and liner.

Measurement of Force Required for Stamping, Pressing and Extruding Operations

Foreign abstract, condensed from "Electrical Methods for Measurement of Forces Required in Chipless Machining Operations", F. Faulhaber, *VDI Zeitschrift*, June 24, 1944, page 347.

ELECTRICAL INSTRUMENTS have recently been developed for measuring forces on presses, hammers and similar machines for shaping of metals. These instruments can readily be installed and do not require any appreciable alterations of the machines.

Three main methods of installing the measuring box are shown in Figs. 1, 2 and 3. In Fig. 1 the measuring box A is placed beneath the tool B; this method is employed when the forces are relatively small as on small stamping presses. In Fig. 2 the measuring box A is between punch B and die C; this arrangement is used on large presses and extrusion machines. In Fig. 3, which shows a force press operation, the measuring box A is freely supported by the shell C and a liner E.

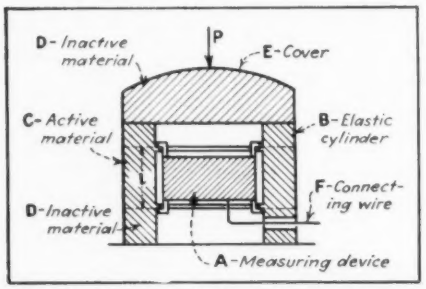


Fig. 4—General design of a measuring box with an internal measuring device.

The elastic deformation of a measuring box member is used to measure the forces. These deformations are small because the boxes must be sufficiently rigid to withstand heavy loads. The measuring boxes are light in weight, and are short enough to give correct values even when the load is eccentrically applied.

Calibration of the boxes can be represented by straight lines that have the same slope for various measuring boxes. This requirement is essential because it makes possible the use of several boxes in series.

Light weight of the measuring instruments is the most important condition. Forces cannot be measured accurately when the box weighs several hundred pounds. Also, heavy boxes are difficult to install properly.

The general design of a measuring box with an internal measuring device is shown in Fig. 4. To avoid highly sensitive recording instruments, the design is based on a relatively large elongation ΔL (practical values lie between 0.0040 and 0.0004 in.) Elongation is calculated from Hooke's Law. Where

P = applied force
L = measuring length
q = sectional area
E = Modulus of elasticity
$\Delta L = PL/qE$

The weight G of the elastic body of measuring length L, made of material having a specific weight γ, is determined from

$$G = \gamma Lq$$

and since the stress σ is P/q

$$G = \gamma \Delta L P E / \sigma^2$$

Weights of different measuring boxes can conveniently be compared on the basis of the "specific Load K", that is, the load that a box can sus-

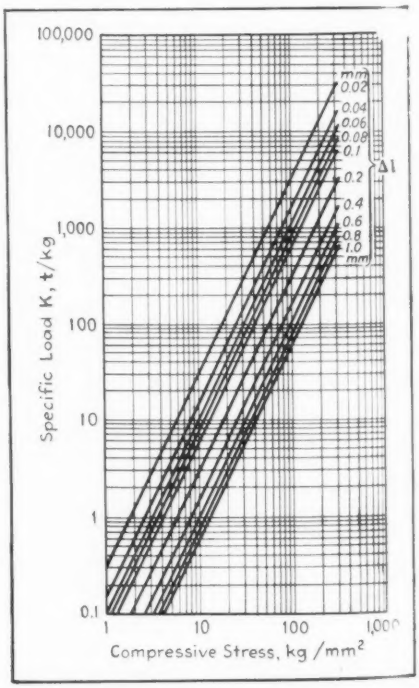


Fig. 5—Specific load as a function of the compressive stress at different elongations.

tain for each kilogram of weight;

$$K = \frac{P}{G} = \frac{\sigma^2}{\gamma \Delta L L}$$

From this equation the specific load varies proportionately to the square of the compressive stress, provided that the elongation, or sensitivity, ΔL remains constant, Fig. 5. The measuring length L varies inversely proportional to the compressive stress σ. An appreciable portion of the height also varies proportionately.

Practical values for the specific load K are 1 to 3 tons per kg for hydraulic boxes and 2 to 10 tons per kg for old type electrical boxes. In a recently developed electrical box the specific load could be increased to as much as 77 tons per kg. The basic design of this box is shown in Fig. 6. Such a large value for K can only be obtained by increasing the compressive stress σ, which in turn requires a hardened spring body and its separation from the measuring device. The box shown in Fig. 6 was designed for a maximum load of 500 tons, although it can be overloaded 100 percent. The box weighs 14.3 lb, its largest diameter is 5.8 in., its height is 3.2 inches.

The box shown in Fig. 7 was developed for installations where the axis of the box does not stay in the direction of load application because of deflections within the machine, that is, where the load acts eccentrically on the measuring box. It is obvious that such eccentricity must not affect the recording of the true value of forces.

The independence of the recorded force from the direction of load application results from one side of the elastic cylinder being compressed more than the other side when the load is off center, while the measuring device registers only the averaged deflection. This explanation is only approximately correct, because actually the independence results from compensation of the shearing forces generated in the various segments of the elastic cylinder. The cover C likewise plays an important role in this respect because it is shaped so as to distribute the applied load with a certain continuity over the elastic body.

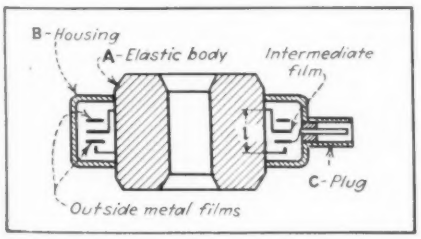


Fig. 6—Measuring box with an external measuring device consisting of a differential condenser.

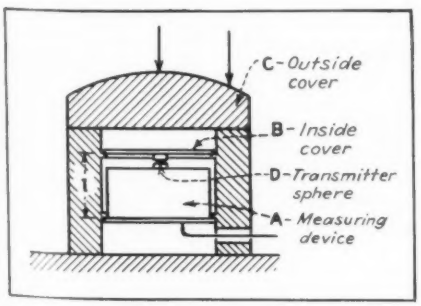


Fig. 7—Measuring box used for loads that are eccentric to the box.

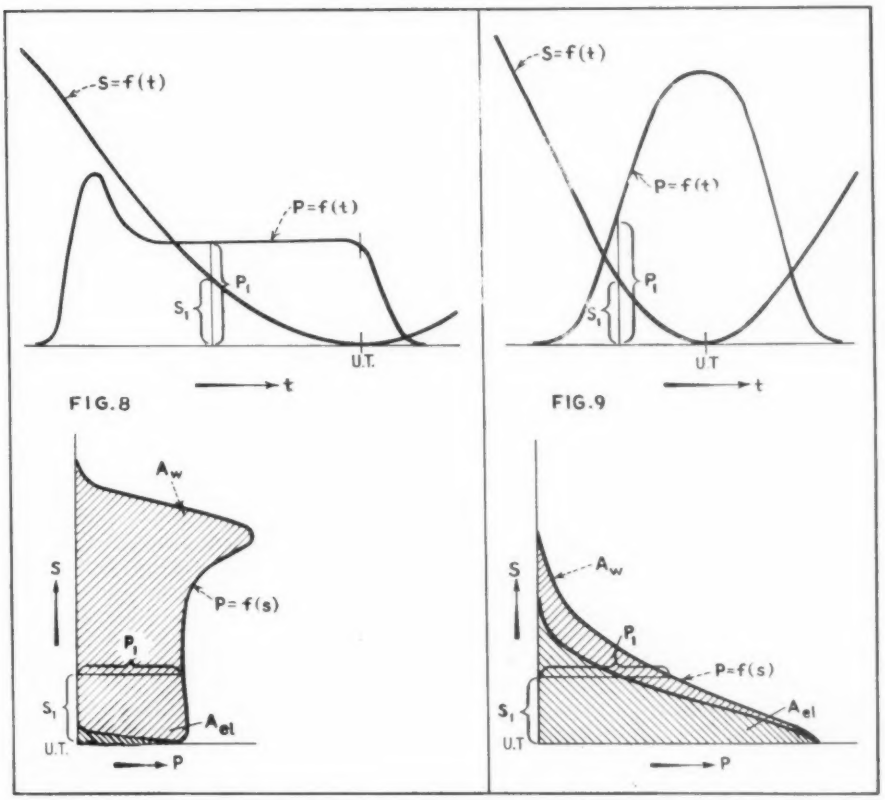


Fig. 8—Curves for a typical drawing operation on a crank press. Fig. 9—Curves for a typical stamping operation on a crank press.

Many other designs were developed during the investigation by "trial and error methods" because calculations of stress distribution are extremely difficult to make.

The measuring instruments should have high natural frequency, particularly when used on hammers. For machines like presses, high speed presses, and shears (except billet shears), the natural frequency need not be higher than 1,000 to 1,500 cycles per sec. It was found that a type of operation, such as cold pressing versus hot pressing, has only little effect on the occurring maximum frequencies. It seems that frequencies depend upon the design and rigidity of the machine rather than on the operation performed.

An accuracy of 1.5 to 2 percent can easily be obtained without requiring the boxes to have a high measuring accuracy, because variations in the work material are usually high in comparison with the average accuracy of the instruments.

For nonsymmetrical workpieces it is advisable to couple several measuring boxes placed at various points of the workpiece, and thus be able to determine the total force at any instant of the operation, in addition to determining the local force at the respective sections. This method is of interest when phase differences in the operation occur. Such coupling can result in correct values only when the calibration characteristics of the various boxes are parallel lines.

The measuring element in the box is protected against dust and humidity and also against mechanical damage. The condenser plates should be separated at least 0.040 inch.

Amplifier, recorder, oscillograph, plugs, and synchronizer required for measuring the forces are built into a self-contained unit, which can easily be carried when measurements are taken in the shop. Independence of the recorder from variations in electric current in the plant is secured by a glimmering stabilizer for the anode and an iron-hydrogen resister for the heater.

In addition to the Force-Time (P, t) curves recorded by the oscillograph,

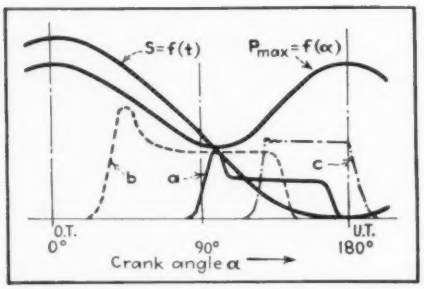


Fig. 10—Force diagrams comparing the several operations that a given press can produce with a given maximum force.

the work required for the production of a part is a desirable quantity to know in the analysis of operations on presses, hammers and similar machines. The box instruments register the force as a function of time only. To determine the work done, it is necessary to measure also the travel distance S as a function of time and to plot S, t curves. From curves representing P by the function $f(t)$ and S by the function $f(t)$, it is possible to find P by the function $f(s)$, thus as shown in Figs. 8 and 9 the work done A is

$$A = \int PdS$$

The S, t curve can either be calculated from the dimensions of the machine (if the operation takes place within a small crank angle of a press) or by taking pictures of the motion with a movie camera.

Assume that information about the utilization of a crankpress with respect to the crank-angle is desired as data for possible improvement in various operations. It is then only necessary, as shown in Fig. 10, to correlate the force diagram of the operation to the curve of the maximum force P_{max} that the machine can produce. Curve A, Fig. 10, is the force diagram for a single drawing operation starting at about 90 deg. crankangle. Comparing this curve with the P_{max} curve it is evident that the machine is poorly utilized. Shifting the start of the operation to the upper reversing point OT of the stroke by employing a rocking punch (Curve B, Fig. 10) allows an appreciable increase in the drawing force and a better utilization of the press. Curve C refers to a cold extrusion operation.

In the work curves Figs. 8 and 9 the areas A_w indicate the work done in deforming the workpiece. Cold extrusion operations have a large A_w, while the work done in stamping operations is insignificantly small. Other operations lie between these two extremes. The deflection of the machine and the tools is indicated by the area between the P,S curve and the abscissa and ordinate that represent the "elastic work" A_{el}. The work A_{el} is lost because it is not used for the production of the workpiece, but it must be expended to get the required force.

It may happen that the work done by the flywheel in deflecting a crank press is greater than that required for deformation of the workpiece, particularly in stamping and coining operations, but this work is regained after the lower reversing point of the cycle is passed. The total work capacity of a press, therefore, equals the sum of the actual and the elastic work capacity.

Conditions are different in drawing operations that are finished at the lower reversing point. The elastic deformation is not represented by an area and cannot be regained. At the instant the workpiece leaves the drawing ring, the stored energy of deformation is released and produces a sudden acceleration.

Information furnished by the PS curve is of much importance when selecting a drive for the machine to suit the expected or known work cycle.

Polarity Indicator

From "Polarity Response From Radio Tuning Eye Tubes" by M. L. Greenough, National Bureau of Standards Technical News Bulletin, Feb. 1948.

BY A SPECIAL CIRCUIT, a conventional "magic eye" tube of the variable shadow type (such as 6E5, 6U5, 6N5) furnishes a polarity-sensitive indication. The circuit was developed for precision instruments, but it may have many other possible applications.

The obvious method of making the "magic eye" tube polarity-responsive is to bias the deflection grid to produce some arbitrarily chosen reference angle, which is marked on the scale over the tube. Positive or negative signals then cause an increase or a decrease of this shadow angle. The disadvantages of such a system are

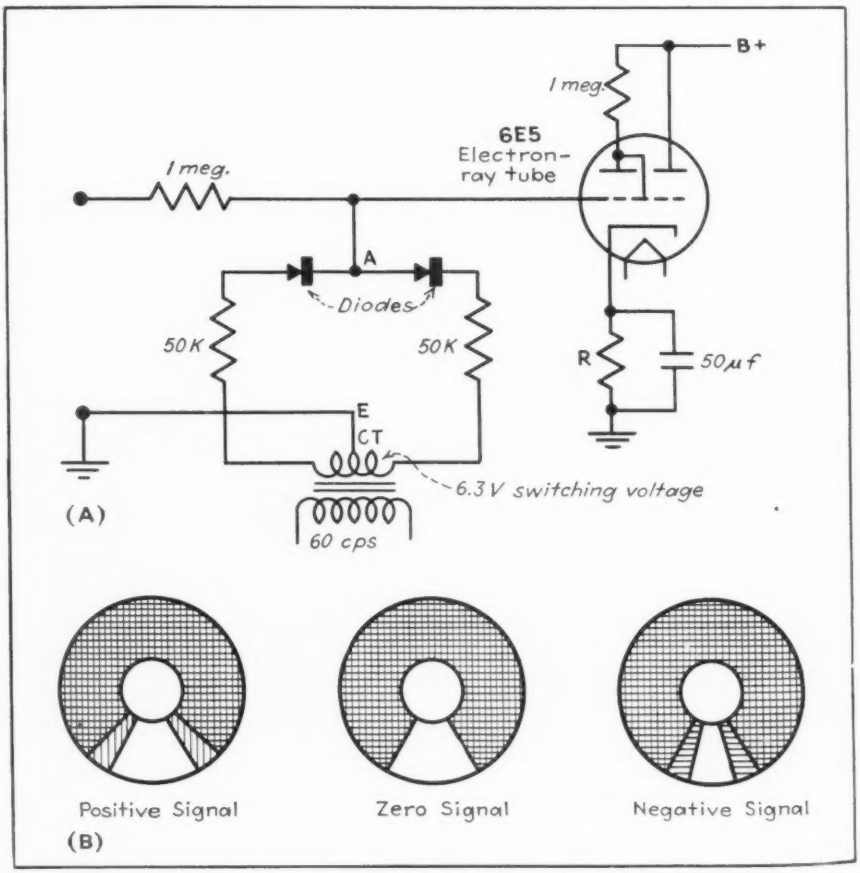


Fig. 1—Polarity response system. (A) Special electronic circuit; (B) typical patterns.

the instability of the reference angle (greatly dependent upon the supply voltage) and parallax of observation. These disadvantages can be avoided by repeatedly switching the signal on and off at a rate fast enough to prevent visible flicker; for example, at power line frequency. By this means two shadow angles are maintained on the tube screen itself. One shadow angle, corresponding to zero input, appears half the time, and during the remaining time the angle is that due to the amplitude of the applied signal. Zero signal input is indicated when the edges of these angles coincide.

Typical patterns for positive, zero, and negative signals are shown in Fig. 1. There appears to be a half-illuminated angular sector whose width is proportional to the deflection signal; and which lies on one or the other side of a reference line as determined by signal polarity.

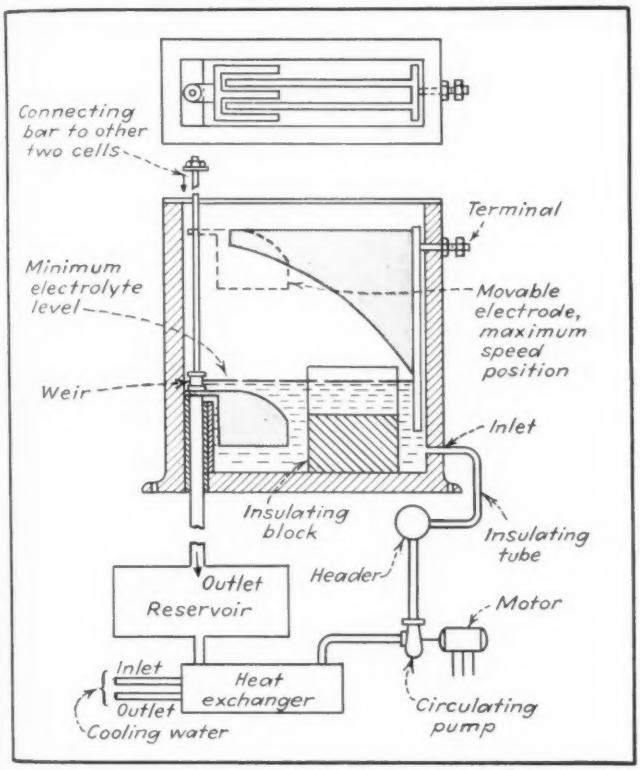


Fig. 1—Arrangement of cell with electrode below electrolyte.

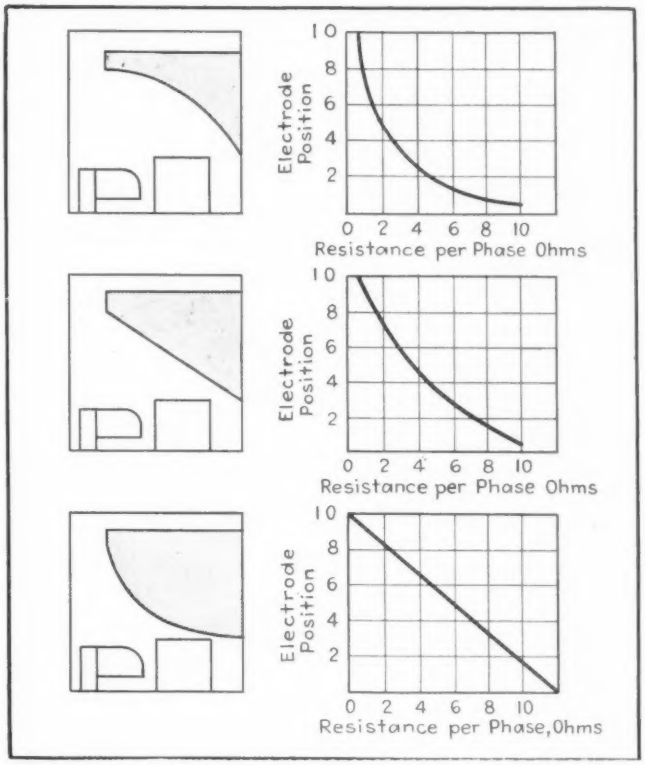

Electrode Position
0 2 4 6 8 10
Resistance per Phase Ohms
Electrode Position
0 2 4 6 8 10
Resistance per Phase Ohms
Electrode Position
0 2 4 6 8 10
Resistance per Phase, Ohms

Fig. 2—Liquid rheostat gives equal steps of controlled variable.

Compact Liquid Rheostat Design

From "A New Liquid Rheostat for Steel Mill Use" by T. B. Montgomery and A. C. Halter, Allis-Chalmers Manufacturing Co., presented at 1948 General AIEE Meeting, Pittsburgh, Pa.

A NEWLY DEVISED LIQUID RHEOSTAT regulates the length and area of the current path between electrodes by changing the level of the electrolyte. This gives a wide range of resistance in small space. Also, by proper design of the stationary electrode and insulating block almost any kind of "resistance" versus "position" curve can be obtained.

As shown in Fig. 1, the container or cell of insulating material is long and narrow. On one end is the stationary electrode that extends nearly the full length of the container at the top and slopes back to the supporting end near the bottom. At the other end of the cell is a movable weir to which is fastened a smaller electrode slightly below the level of the weir. Mounted on the bottom of the cell between the two electrodes is an insulating block. Three such cells are mounted side by side with their weirs connected to a common lifting mechanism. This connection also serves as an electrical connector between the three movable electrodes for the neutral. The electrolyte inlets are connected to a common header by means of insulating tubes. A reservoir, heat exchanger, circulating pump and lifting mechanism for the weirs complete the unit.

In operation, the electrolyte enters the cell through the insulating tube. After it has filled the cell to the level of the weir, it passes through the outlet pipe into the reservoir which lies directly beneath the cell. From the reservoir the liquid passes into a heat exchanger, through the pump, and back into the header to repeat the cycle. With the weir in its lowest position, the length of the current path through the electrolyte is the longest, giving maximum resistance. When the weir is raised the liquid level will also rise (keeping the neutral electrode covered); thus the length of the conducting path will be decreased, until the electrodes intermesh at the upper limit giving minimum resistance.

This unit is well suited to applications that require a large range of resistance. Also, equal steps of the controlled variable for equal steps of rheostat position can be obtained as shown in Fig. 2. Size is small, considering the extreme ranges of resistance obtained and the amount of heat it can dissipate. A liquid slip regulator giving 80 percent speed reduction on a 350 hp fan drive, is 67 in. high and requires a floor space 26 by 36 in.

The electrolyte used is a solution of (approximately three percent) sodium carbonate in clean water. This solution has a negative temperature coefficient over its operating range, as shown in Fig. 3.

Liquid rheostats are particularly

suitable on small drives that require stepless and precise control. Such applications include induced and forced draft fan drives, centrifugal pumps, and blower and compressor drives. They are also well suited for large flywheel set motor drives where they produce a cushioning effect for good load regulation. Another application is for a large variable speed drive in which the load at any given speed is fairly constant, and where a high degree of accuracy is required in speed output. This is because the rheostat is stepless and can handle large amounts of power.

The type of control element used is determined largely by the accuracy and response required, and can be operated either manually or automatically. Manual control is used where a small drift is not objectionable and where accurate settings are not required. Automatic control may be obtained with air or oil operated cylinders or a pilot motor under Regulex control. This type of control gives variable response, and eliminates drift due to temperature changes, but the

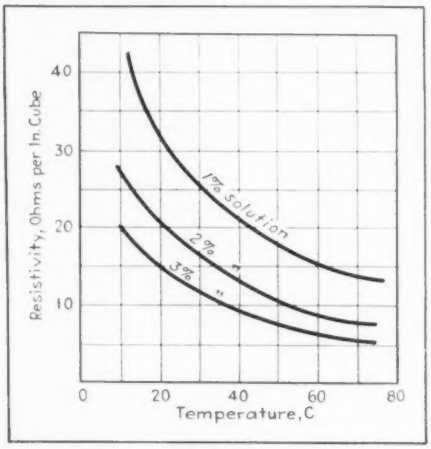


Fig. 3—Electrolyte is solution of sodium carbonate in clean water.

rate of acceleration is limited by the capacity to the electrolyte pump. Such control is used to regulate speed.

Where extreme accuracy is required as in wind tunnel drives, the liquid slip regulator used with a Regulex generator responding to an electronic amplifier provides an ideal combination.

Orientation of Polystyrene

From "Stretch Orientation of Polystyrene and its Interesting Results," by James Bailey, Plax Corporation, presented at the annual meeting of the Society of Plastics Engineers, January 21, 1948.

ORDINARY PROCESSES OF MANUFACTURE result in molecular orientation, which may produce either strength or weakness. Stretching produces the greatest strength in the direction of stretch and is useful only in monofilaments. Wide sheets require bilateral stretch. Compression molding may produce sheets tough in both directions or sheets weak in one direction. Injection moldings require careful die design.

The long relaxation time of stretched sheets permits lamination without serious loss of strength and toughness. The tendency to relax enables preforms of wound or stacked sheets, confined in a simple mold, to consolidate themselves when heated, without external pressure.

Polariscopic study of strains requires considerable knowledge and experience since hot stretching may produce ten times as much birefringence as rupturing stress at room temperatures, and the hot and cold birefringence are of opposite sign. Moreover, equal bilateral stretching produces no evidence of strain.

Strength and toughness are a function of size, and small fibers can be made which show cold stretching up to 85 percent. Thin, bilaterally stretched sheets show stretch up to 25 percent. The surface is a very important factor in strength, as is also the molding powder formulation.

Continuous Laminating and Coating

From "Continuous Laminating," by Cecil W. Armstrong, consultant, Burket, Indiana, presented at the annual meeting of the Low Pressure Industries Division, Society of the Plastics Industry, January 15, 1948.

A DEVELOPMENT that may mean cheaper surface and structural laminates is the continuous coating and impregnation of rolls of many different sheet materials. The process consists essentially of : (1) Combining continuously two or more resin-wetted sheets of suitable materials between separable covers; and (2) continuous heat-curing of the laminated stock at atmospheric pressure.

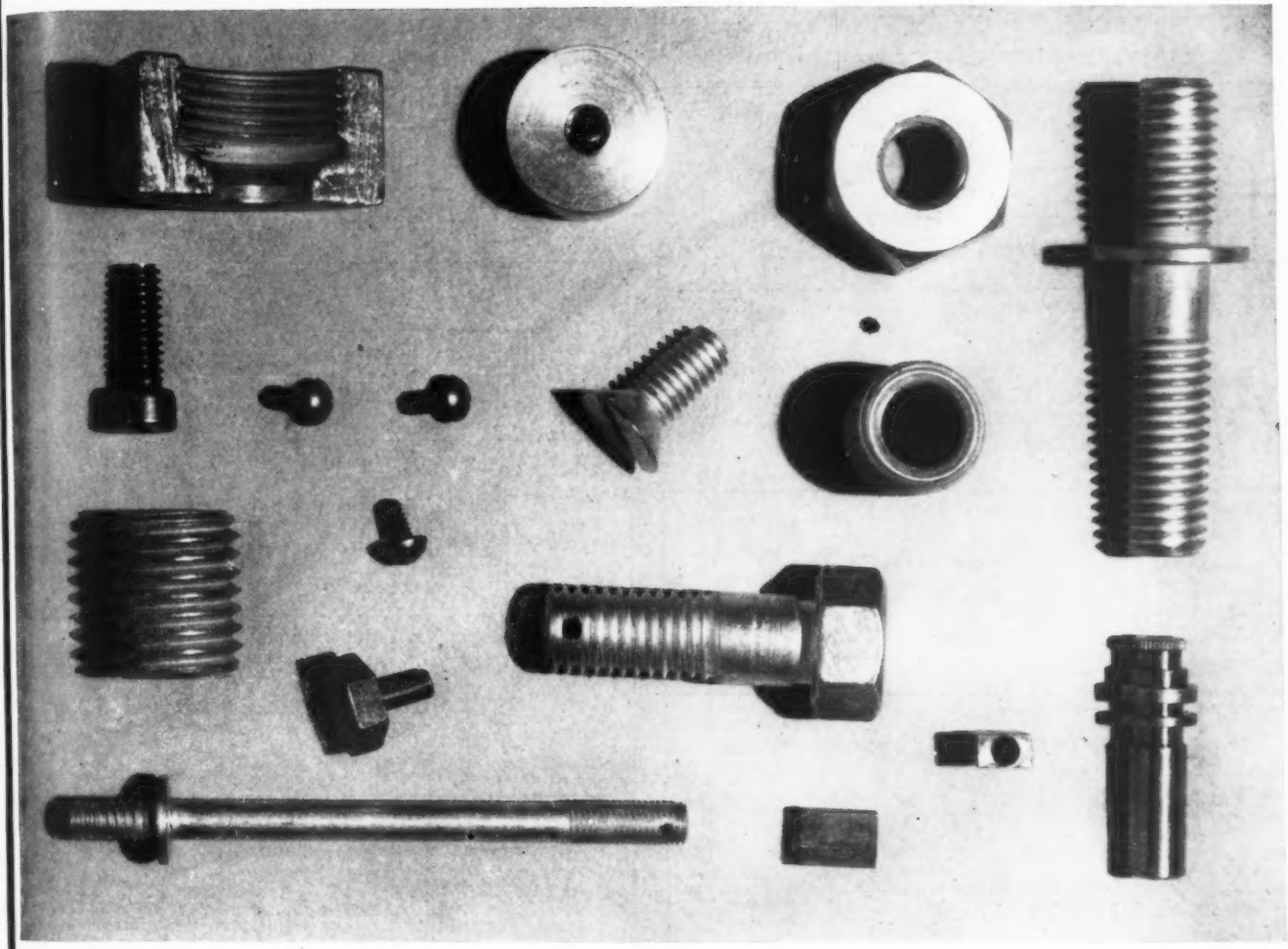
The resins are usually polyesters. Filler materials include: Paper, cotton, rayon, and glass fabrics; cotton, rayon and glass fiber-bonded mats; aluminum foil; and aluminum foil bonded to paper. Cover sheets include cellophane, resin coated paper, and metal belts.

Any one of these filler materials can be combined with any other or combination of fillers. The selection depends on the desired physical properties of the end product, economic considerations, and availability of materials. It is interesting that the possible combination of fillers is not limited to fibrous materials; aluminum foil can be included within the laminate, to obtain cigarette-burn resistance.

The accompanying table shows that tests should be made on rigid paper-base polyester-resin laminates for heavy duty surface applications. With other fillers and for other uses, many of these tests are not applicable.

Tests for Continuous Paper-Base Surface Laminates

Property	Tests
Hardness	Barcol Impressor (Indentation hardness), Rockwell hardness tests.
Scratch resistance	Venus Pencil scratch test—determined by the hardness of the pencil producing the scratch. Fingernail coin edges, and the like.
Wear Resistance	Taber Abraser tests, CS-17 wheel. 1000 gram load—weight loss per 1000 rubs, number of cycles to damage printed or pigmented surface sheet.
Impact Resistance	Resistance of surface coating to fracture on dropping of falling ball or blunt instruments.
Moisture Absorption	Twenty-four hour water immersion test, gain of weight. ASTM 570–42.
Resistance to Staining	Staining materials placed on surface, covered with watch glass cover, left over-night or for specified duration; examination for stains. Commonly used household chemicals include: Cold water hot water, 1 percent sodium hydroxide, laundry soap, 10 percent bisulfate, 3 percent trisodium phosphate, ammonia, 10 percent citric acid, iodine, mercurochrome, alcohol, vinegar, grease, mustard, ink, pencil, crayon, lipstick, and others.
Colorfastness	Colorfastness to light. ASTM D620–45T.
Resistance to heat	a) Boiling water, b) Hot pans, flat iron—275 F for five minutes.
Grease pencil test	Surface rubbed with china marking pencil, rubbed clean with rag and examined with low-power magnification to detect surface pits and voids.
General appearance	Visual inspection of large areas for surface defects such as dry spots, lines from cover sheets, freedom from waviness, curl, warpage.
Resin content	Weight of unit area of product divided by weight of unit area of filler materials to determine uniformity of product.



Typical parts produced on screw machines. Tolerances for many of their dimensions are not often specified on engineering drawings.

Shop-Run Tolerances

PART II

Shop-run tolerance data for parts produced on screw machines and general machine shop equipment. Eccentricity and angularity tolerances for parts threaded on screw machines.

L. M. NIELSEN
General Electric Company

MANUFACTURING ECONOMIES made possible by the development of hand screw machines, and later semi-automatic and automatic screw machines, have caused this type of machine tool to be segregated in most plants so as to be under the supervision of specially trained personnel.

High productivity of these machines enables them to supply several divisions with parts at a lower overall cost than would be possible with either general purpose tools or screw machines that would not be fully utilized in one division or given the specialized tooling and attention that is possible in a screw machine division.

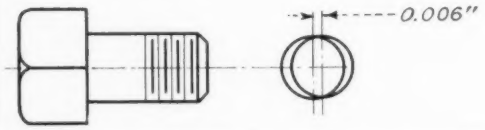
The variation in tolerances, finish and other requirements between different operations make it advisable to set up shop-run tolerances for screw machine operations. Usually engineers and inspectors follow a particular line of work and explain the functional requirements or finish. Shop-run tolerances indicate specifications that avoid much confusion.

The eccentricity tolerances within which various types of parts can be maintained economically on the usual types of screw machines are shown in Table I. The angularities between thread and body, or thread and thread are shown in Table II. These limits apply on work up to 10 in. long, which usually covers a majority of the parts made on screw machines.

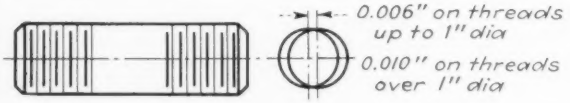
Manufacturers strive to produce parts as close to zero variation as possible, but wear and tear on machines, tools, and fixtures as well as the human element makes it necessary to plan for some variations. When inspectors find a tendency for the work to approach shop-run tolerance limits, the maintenance man or the tool setter can be called in to make necessary corrections. Tables III and IV are the variations to which the preceding comments will apply. The squareness of faces under bolt heads, screws, and nuts, shown in Table IV, is important mainly where high stress is encountered, but it is advantageous to specify what may be expected on commercial work so that a surface requiring closer attention may be so indicated on the drawing. The tolerances given in Table III for turning, boring, and fac-

TABLE I — ECCENTRICITY TOLERANCES FOR SCREW MACHINE WORK

THREAD WITH BODY

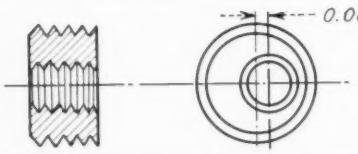


THREAD WITH THREAD

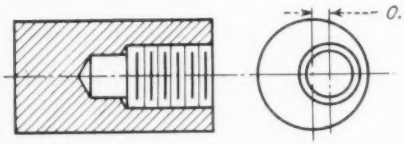


THREAD WITH THREAD

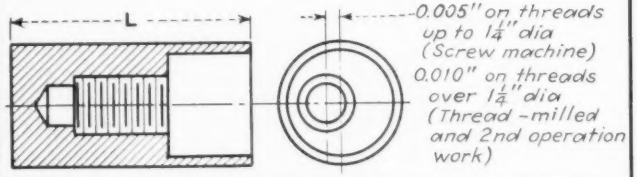
THREAD WITH THREAD



THREAD WITH O D OF BODY



THREAD WITH DRILLED HOLE



THREAD WITH THREAD

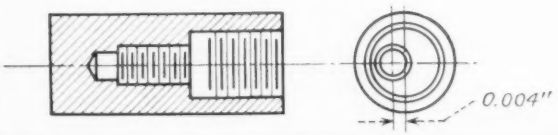
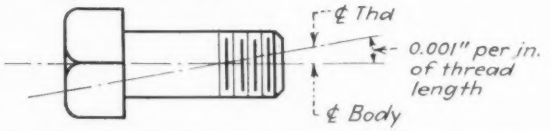
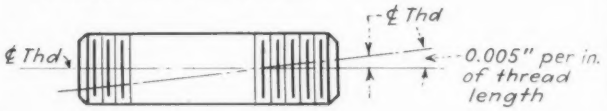


TABLE II — ANGULARITY TOLERANCES FOR SCREW MACHINE WORK

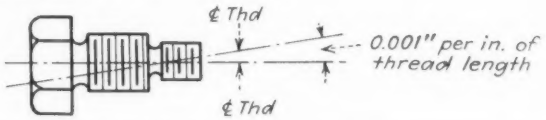
THREAD WITH BODY



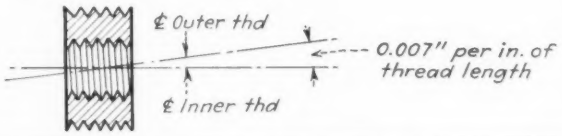
THREAD WITH THREAD



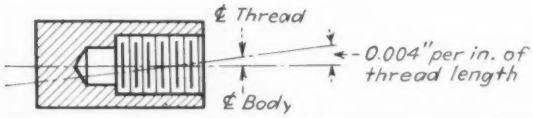
THREAD WITH THREAD



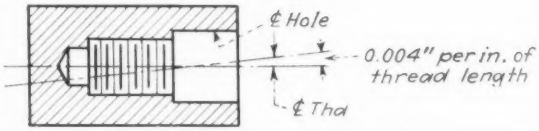
THREAD WITH THREAD



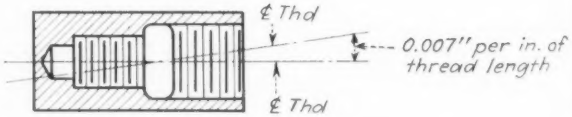
THREAD WITH O D OF BODY



THREAD WITH DRILLED HOLE



THREAD WITH THREAD



NOTE — *Shop-run tolerances on angularity apply only to work up to 10" long*

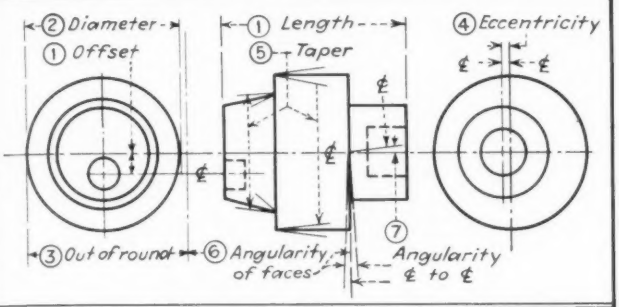
ing operations can be used on hand screw machines, chucking machines, and second operation parts. These tolerances are given for dimensional variations where much misunderstanding can occur.

The reliefs used where threads are close to a shoulder or run into a blind hole that cannot be drilled deep enough to provide clearance for chips are shown in Table V. These also apply where a bolt or screw extends deeper than perfect threads would permit. Tapping such holes, even with a bottoming tap, is difficult without chip clearance. This practice is not used on holes less than ¼ in. diameter. The drilled hole should be deep enough to allow for imperfect threads and provide space for chips.

Certain other standard practices should be defined so that they may be mutually understood. The following are typical examples:

SHARP CORNERS. Unles otherwise stated on the drawing, these should be "burred." Practical limits for this are: Up to 1 in. dia., 0.003 in. to 1/64 in.; to 3 in. dia., 0.003 in. to 1/32 in.

TABLE III — GENERAL TOLERANCES FOR SCREW MACHINE WORK

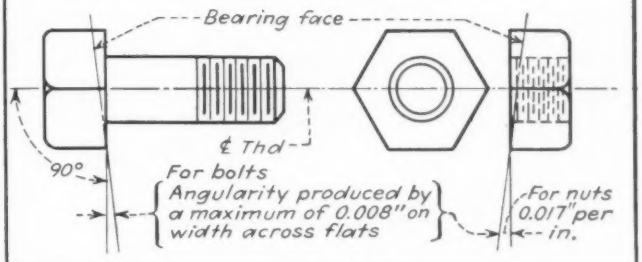


①	Length	0" to 1/4"	Over 1/4" to 24"	Over 24" to 72"	Over 72"	
	Tolerance	±0.008"	±1/64"	±1/32"	±1/16"	
②	Diameter	0" to 1/4"	Over 1/4" to 24"	Over 24" to 72"	Over 72"	
	Tolerance	±0.008	±1/64"	±1/32"	±1/16"	
③	Out of Round	For all diameters, these factors are to be within the tolerance on diameter, whether the tolerance is on the detail drawing, or the shop-run tolerance on diameter applies				
	Tolerance					
④	Eccentricity					
	Tolerance					
⑤	Taper					
	Tolerance					
⑥	Angularity	Faces and shoulders				
	Tolerance	Max 0.005" per ft of surface width measured radially				
⑦	Angularity	Center line to center line				
	Tolerance	Max 0.010" per ft				

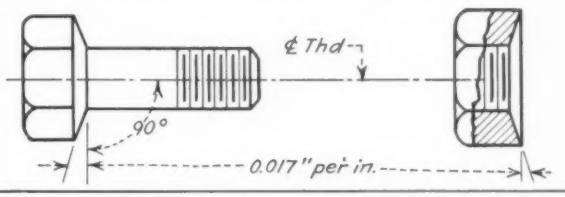
The dimensional tolerance may not be exceeded by any combination of other tolerances affecting the same surface or surfaces

TABLE IV — BEARING FACE ANGULARITY TOLERANCES FOR SCREW MACHINE WORK

THREAD WITH BEARING FACE



CONVEXITY OR CONCAVITY OF BEARING FACE



BEARING FACE

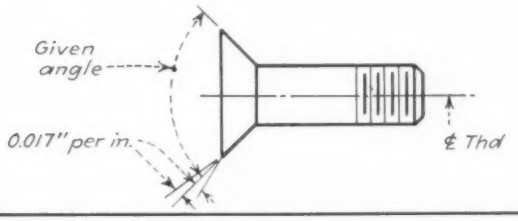
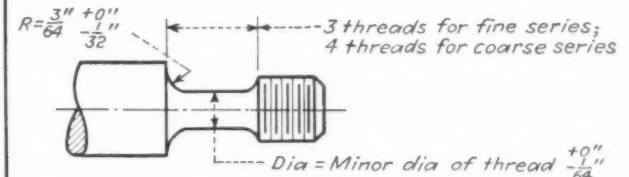
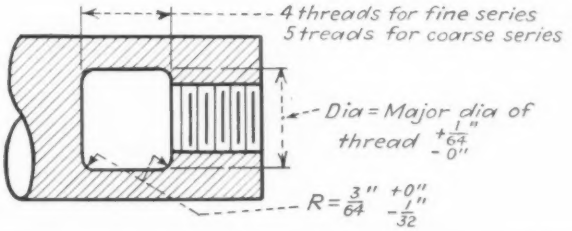


TABLE V — THREAD RELIEFS FOR SCREW MACHINE WORK

EXTERNAL THREADS



INTERNAL THREADS



and over 3 in. dia., 0.003 in. to 1/16 in., all on a 45 deg angle.

CHAMFERS, INTERNAL AND EXTERNAL. Chamfers require an additional operation and should not be confused with "break corners" or "burr". When chamfers are required they should be specified on drawings by sizes as: 1/16 in. chamfer. The angle of chamfer can be standardized, such as 45 degrees unless otherwise specified. Exceptions can be made so that existing tools or equipment will not be affected. Bolt heads and nuts, for example, can be made to a different standard. The angle of a standard chamfer can be specified to allow a tolerance of plus or minus 5 degrees. If not shown on drawings, it can be understood that shop practice of "break corner" will always be followed.

CHAMFERS ON THREADED ENDS. Chamfers, unless otherwise specified, can be made to extend below root diameter of thread, and the depth below the root diameter specified shall not exceed one-half the depth of thread. Squared ends with chamfered edges are

preferable to rounded ends, since the rounded ends require form tools and radius gages.

CORNER FILLETS. When a turned diameter runs into a larger diameter a square corner is hard to maintain and presents a definite stress raiser, or a weak point. It should not be used unless the design requires it. A radius is always preferred. Unless otherwise specified, corner radii can be made to a radius of 1/64 in. for diameters up to perhaps $\frac{3}{8}$ in., and 1/32 in. radius for larger diameters. Since fillet dimensions may be critical, they are usually specified on the drawing.

FLATNESS OF ENDS. Cut-off ends can be expected to vary as either concave or convex to approximately 0.003 in. max., per inch of diameter; and faced ends to 0.001 in. max. per inch of diameter.

CLASS THREAD. All threads, either external or internal, can be made to conform to a specified class unless otherwise indicated on the drawing.

GRINDING RELIEF ON SHAFTS. When a ground diameter runs into a larger diameter, a relief groove near the face of the larger diameter should be provided. Unless an undercut is shown on the drawing, these are practical dimensions: Width, 0.030 in max.; depth, 0.003 in. to 0.005 in. or 0.006 in. to 0.010 in. diameter below the finished diameter called for on the drawing. The radius in such cases can be 0.004 in. to 0.007 in. near the face from the larger diameter, and leave at an agle of 8 deg to 12 deg.

TOLERANCE FOR HOLES. Tolerances for holes drilled as part of screw machine operations are shown in Table VI.

General Machine Shop

Where a complete unit is built in a factory, shop practices can be developed that maintain a standard of tolerances and finishes for satisfactory operating characteristics in the product and commercial acceptability to the market. These local standards will vary with the product and the standards the owners set for themselves as well as with the market to which they cater.

Many points of similarity are found in different types of shops. Some shops building aviation and marine equipment require close-tolerance production, while others such as builders of industrial control equipment use a large number of molded and punched parts on which wider tolerances are acceptable. Also, there are many shops that have a mixture of requirements for both close and wide tolerance work.

Holes that can be drilled, punched, swaged, etc. can have the word "hole" follow the dimension on the drawing, permitting the method of machining to be determined by the factory. This same principle can be observed wherever alternate methods of production may be used. The factory can thus select the tools and methods, best adapted to both its available facilities and past experience, and produce a satisfactory part at the lowest possible manufacturing cost.

Typical shop run tolerances on circular bodies indicating allowable variations for: Out-of-round, eccentricity, taper, angularity of faces and shoulders to the centerline and the angularity of diameters with the centerline are similar to those given in Table III. Only the values for angularity tolerances are different from those shown in Table III. For general machine shop operations the maximum angularity tolerance for faces and shoulders is 0.003 in. per ft of surface width measured radially. The maximum center line to center line angularity tolerance is 0.003 in. per foot. Angularity of diameters should not be confused with taper, as the diameter may measure the same on both ends, but may run true with the centerline at only one point along the axis. Also, as pointed out in Table III, the combined variation in eccentricity, out-of-round, and taper may not exceed the tolerance on the diameter.

The following values for run-out can be used for holes in the center of parts (run-out being twice the eccentricity) produced on different types of machine tools:

Drills—not to exceed 0.010 in. between outside surfaces and center.

Turning and Boring Machines—not to exceed 0.007 in. between outside surfaces and center.

Lathes—not to exceed 0.005 in. between outside surfaces and center.

Grinders—not to exceed 0.001 in. between outside surfaces and center.

Facing should not be convex or concave more than 0.001 in. per inch of diameter.

Cylindrical parts with thin walls, thin walled rings, half rings or shells which, unless measured in the fixture in which they are machined, will go

TABLE VI—TOLERANCES FOR HOLES DRILLED ON SCREW MACHINES

Basic Hole Diameter	Variation from Basic Size			
	Metallic*		Non-Metallic**	
	Plus	Minus	Plus	Minus
Up to 0.040 in.	0.002 in.	0.001 in.	0.001 in.	0.002 in.
0.040 in. to 0.070 in.	0.003 in.	0.001 in.	0.001 in.	0.003 in.
0.070 in. to 0.128 in.	0.004 in.	0.001 in.	0.001 in.	0.004 in.
.128 in. to 0.228 in.	0.005 in.	0.002 in.	0.002 in.	0.005 in.
1/4 in. to 1/2 in.	0.006 in.	0.002 in.	0.003 in.	0.006 in.
1/2 in. to 3/4 in.	0.008 in.	0.002 in.	0.003 in.	0.008 in.
3/4 in. to 1 in.	0.010 in.	0.003 in.	0.005 in.	0.010 in.
1 in. to 3 in.	0.015 in.	0.003 in.	0.005 in.	0.015 in.
3 in. and over	0.020 in.	0.005 in.	0.007 in.	0.020 in.

(*) Metals, Mycalex or similar non-shrinkable materials.

(**) Non-metallic materials having shrinkable characteristics.

out of shape until assembled with the mating parts frequently present problems. To study such situations, the following methods can be used to arrive at a satisfactory solution:

Where the ratio of inside diameter to the wall thickness dimension is 10 or greater, special consideration must be given to distortion of diameters in making the set-up for machining and clamping, and later measuring. Average diameters may be used to measure the diameters of such parts after all clamping has been released. Six or more measurements can be taken and averaged to obtain average diameter. Outside diameters of such parts can also be measured by flexible rules around the body, dividing the measurement by π. So called "pi" rules are now available.

Tolerances for flat work are shown in Table VII and apply, of course, only where specific tolerances are not given on the drawing. Flatness can be measured either with a straightedge and a set of feelers, or by placing the part on a surface plate and using feelers around the edges of the part. Parallelism is a dimensional tolerance that can be measured accordingly.

The tolerance on length is used where holes or other features on an arc or circle are spaced by giving the length of the cord rather than the angle. This method is also used for dimensioning holes located in a straight line on a flat surface. The lean, or tilt of a drilled hole is determined by the angularity tolerance where the hole is at a 90 degree angle to the reference surface.

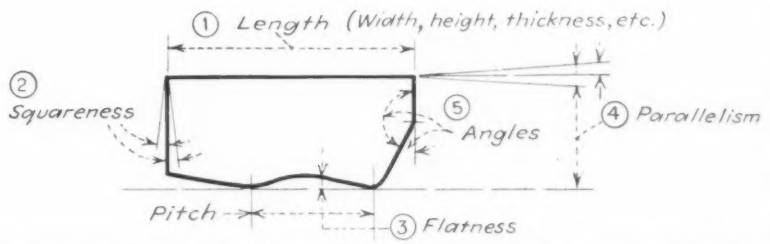
Many new types of machine tools that will improve quality by maintaining close tolerances and better finishes are being manufactured. Often the cost of manufacture is reduced. For example, one new type chucking machine produces pieces of improved quality by using an accurate indexing spindle and rigid construction. High speeds are provided for improving finish by using carbide tooling. The cost of the operation is reduced 50 percent below that of the previous machine because of the high speeds and feeds and features that reduce loading time.

Internal grinding operations in holes over 1 in. dia give closer tolerances than reaming and result in less scrap. Thread rolling machines can be used for producing threads up to 2 in. dia within a 0.0005 in. variation in size. Broaching and plunge grinding operations also are used to reduce cost without reducing quality.

Since the shop-run tolerances for individual operations are constantly being decreased by improved manufacturing machinery and methods, the standards have to be revised to suit these varying conditions.

Shop-run tolerances for other specialized manufacturing operations such as forging, broaching, welding, etc. can be developed to suit the requirements of the particular organization. For example, studies made on flame-cut and welded parts can be the basis for shop-run tolerances on dimensions, angles, etc as well as on the surface finish of flame-cut and welded seams. Allowable variations for this type of work depend upon the size of the pieces used. Often it is advantageous to take photographs of welded or flame-cut surfaces to indicate the general appearance of acceptable work.

TABLE VII — TOLERANCES FOR FLAT WORK



①	Length, Width, Height	0 to $\frac{1}{4}$"	Over $\frac{1}{4}$" to 24"	Over 24" to 72"	Over 72"
	Tolerance	$\pm$0.008"	$\pm \frac{1}{64}$"	$\pm \frac{1}{32}$"	$\pm \frac{1}{16}$"

②	Squareness	Tolerance = { 0.001" per in., plus 0.005" up to a maximum of 0.015"		
③	Flatness	Finish Symbol	Tolerance When pitch of high spots, peak to peak is;	
			12" or less	more than 12"
		f_3	0.0001"	0.0001" per ft of pitch
		$f_{3\frac{1}{2}}$	0.0002"	0.0002" " " " "
		f_4	0.0005"	0.0005" " " " "
		f_5	0.001"	0.001" " " " "
		f_6	0.002"	0.002" " " " "
		$f_{6\frac{1}{2}}$	0.0035"	0.0035" " " " "
		f_7	0.007"	0.007" " " " "
		f_8	0.016"	0.016" " " " "
④	Parallelism	Tolerance { 0.001" per in. plus 0.005" up to a maximum of 0.015"		
⑤	Angles	Where angles are expressed in degrees the tolerance = $\pm$ 1°		
		Where angles are dimensioned by coordinates the tolerances on Section ① above control		

The dimensional tolerance may not be exceeded by any combination of other tolerances affecting the same surface or surfaces

Courtesy Air Reduction Co.

Increasing the speed of an open-hearth furnace melt, a worker inserts a water-cooled oxygen impingement lance used to melt floaters. Oxygen is used in the refining and melting processes as a chemical reagent and to make more complete combustion of fuel.

Large Volume Oxygen Meets Industry Demands

VOLUME USE OF OXYGEN and industrial ability to produce large volumes of oxygen have necessarily progressed together. They have reached a point where oxygen is available and is being used in large quantity in the production of steel, as a chemical reagent, and in the synthesis of liquid fuels.

The Germans initiated production of large volumes of low-purity oxygen, by the Linde-Frankl process for two reasons; both resulting from pressure of global war. Insufficient coking coals were available to meet all demands and low-grade, sub-bituminous brown coals had to be used. German industry was taxed to the limit and had to get all available production from the facilities located within its sphere of influence.

Producer gas formed by burning the low-grade coal was too low in Btu content to be used as produced. To increase its effectiveness, it was burned in an enriched air stream. This made the foundation of the expanded high-volume use of oxygen.

During the period between the two world wars, American use of oxygen was greatly expanded. This expansion was accounted for by industries in the steel and heavy construction fields. High-purity oxygen was used for cutting huge billets and expanded output by reducing time per unit produced. Other uses for large amounts of oxygen included: Flame-hardening, cutting of stainless steel, and de-scaling of large billets, furnace tapping and ingot splitting. Though the oxygen used in all these processes was of high purity, the members of the steel industry were beginning to gain experience in oxygen use. At the present time, this experience is making the conversion to quantity oxygen as a production tool much easier.

At the beginning of World War II, military needs pointed up the need for making portable oxygen-producing equipment. High altitude flying and forward area maintenance required adequate supplies of high-purity oxygen.

Answering the requests of the military forces for portable oxygen equipment, the Office of Scientific Research and Development, designated the M. W. Kellog Co. to act as the central engineering organization for the development, design and testing of oxygen plants.

The units that were designed to meet the OSRD requirements were all small producers of high-quality oxygen. They were built to operate on the principle of low temperature air fractionation. Though these plants will not show in the huge volume production that is needed to match present demand for oxygen—and the still larger anticipated demand of the future—they have aided in design of present plants. They showed the relation between the quality of the final gas and the volume of that gas.

Men close to the field of volume oxygen use feel that oxygen quality will be definitely divided between two purity groups: 40 to 60 percent and 80 to 100 percent. Present conception of "cheap" oxygen seems to imply a

purity between 90 and 95 percent.

Throughout the war, the Elliot Co. has been interested in oxygen and its use in large volume. They have recently announced a process for large-scale production of oxygen without use of the Linde-Frankl method.

In this process, pre-conditioned air is cooled to —300 F and distilled in a special distillation column into its components of oxygen and nitrogen. The later is valuable for by-product chemical production, and the oxygen is in such form that it can be piped directly to the point of use.

A pilot plant, which has been operating for more than two months, has shown that the new process can operate indefinitely without necessity of "defrosting" shutdowns. These shutdowns have been responsible for many of the bad features of other systems of producing high-volume oxygen.

Although much has been said about the Fischer-Tropsch process for synthetic liquid fuel production, less than 8 percent of Germany's annual production of liquid fuels was produced by this process. The hydrogenation process was responsible for 40 percent of liquid fuel production.

However, with the Fischer-Tropsch method of turning coal or natural gas into gasoline, fuel oil and a long list of hydrocarbons is being investigated in this country. All of these studies will require the use of large volumes of oxygen. Natural gas is to be used in new plants in Texas and Kansas for producing synthetic fuel. The oxygen is used to change the natural gas to the synthesis gas. Oxygen will also be used in large quantity in making synthetic liquid fuels with coal and coke as the base materials. Here, the synthesis gas is made by the action of oxygen on the carbonaceous fuels.

One of the major drawbacks of the original system of liquid fuel synthesis, in the United States, was the inability to change German methods into production processes along American lines.

The M. W. Kellogg Co. had an excellent background in the Fischer-Tropsch process and made valuable contributions in swinging the process into American production. They were the first to adapt the Fluid catalyst principle to liquid fuel synthesis. The Kellogg Co. had much to do with the development of Fluid catalytic-cracking of crude oil, and saw the use to which it could be put in synthetic production.

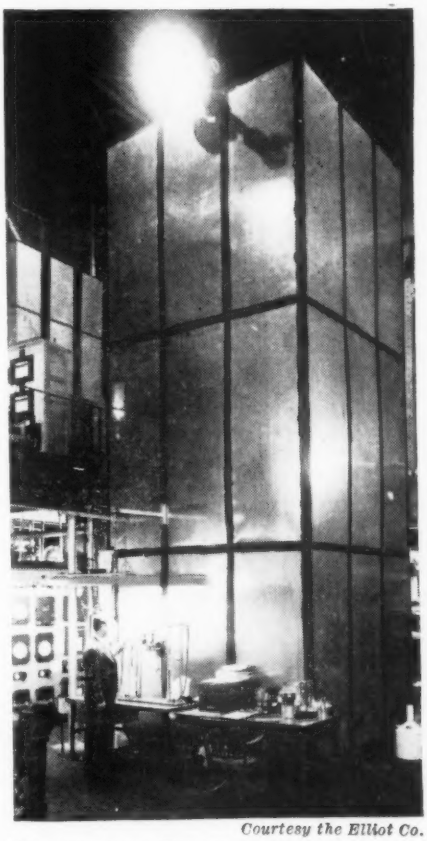
That tremendous quantities of oxygen are needed, can be seen by comparing the production for the year 1946 and some of the estimates for plants being considered. In 1946, 11 billion cu ft of oxygen gas were produced; one synthetic fuel plant estimates a need for 53 million cu ft of oxygen per day. Various estimates in the steel industry range from 600 to 1,200 cu ft of gas per ton of steel produced in open-hearth furnaces.

Anticipated liquid fuel returns from synthetic plants can be seen from figures estimated for the 19 million dollar Brownsville plant of Carthage Hydrocol—a group formed by eight interested companies. The plant will require 50 million cu ft of oxygen and 90 million cu ft of natural gas per day. From these, 7,000 bbl of oil products and 150,000 lb of chemicals would be produced daily.

Chemical byproducts would include: Methyl, ethyl, propyl, butyl and amyl alcohols, acetone, acetaldehyde and, acetic and propionic acids. Volume production of these valuable products will affect chemical industry prices and will absorb some of the heavy expenses of synthetic liquid fuel production.

Uses of oxygen in the steel industry fall into two classifications: chemical reagent used to reduce the carbon content for low-carbon steels, and medium in which to burn fuel to produce high temperatures and quick melting.

The German steel industry recognized these two qualities of oxygen, but did not try to use them in the right places. In applying oxygen to their steel producers, they made no attempt to use it in the open-hearth furnaces. It was used in the Bessemer converter, but gave such a short cycle that it was difficult to control. Oxygen was also used in blast furnaces, but the high temperatures burned out the refractories. After these failures, the use of oxygen in steel making was just about abandoned.



Courtesy the Elliot Co.

Ten ton per day gaseous oxygen pilot plant has run nine weeks and automatically maintained 95 percent purity oxygen and 99.5 percent purity nitrogen. The recovery of oxygen from process air is over 97 percent in this continuous operation.

In the United States, the open-hearth furnace was seen to be the best place to initiate volume oxygen use. In August, 1946, a joint operation by the Koppers Company, Bethlehem Steel Company and Air Reduction Company made its first heat of steel using the high-purity oxygen enrichment process. Oxygen and non-oxygen heats were alternated in the same furnace so that data would have significance. Oxygen in these tests was used to improve combustion.

The degree of enrichment was a question that could not be answered without experiments. The first test was arbitrarily run with 27 percent oxygen in the air. An increase to 33 percent showed no benefits. With enrichment of 25 percent oxygen, about the same results were noted as for the initial heat.

Results of these first tests indicated that oxygen heats were 20 percent faster and used 10 percent less fuel than non-oxygen enriched heats. The saving in fuel was ascribable only to faster melting because the refining time was the same and was not done with oxygen.

Also in August 1946, the Allegheny Ludlum Steel Corp. used large volume oxygen as a chemical reagent in the manufacture of open-hearth steel. Here, the oxygen was used in the refining stage of the production cycle. Oxygen reduced the carbon content of the steel with a saving of time from one to three hours.

It is being found that the quality of low-carbon steel is dependent not only on the amount of carbon removed, but also upon the rate at which it is removed. Oxygen accelerated carbon removal has been found to increase the quality of the steel.

From these simultaneous experiments it can be seen that oxygen will reduce steel making time and can improve quality, while saving fuel and raw materials.

Other applications of oxygen in the field of metallurgy are anticipated. Some will require only small volumes of high-purity gas, but others already indicate the need for low-purity large volumes. The use of oxygen as a reagent in the refining of nonferrous

metals is being developed at present.

It is still too soon to evaluate in dollars and cents the effect oxygen will have in our industry, but it seems the effects will be large. Use of oxygen will also influence design, because metallic materials may have more rigid production controls and may be more accurately specified.

Standards Engineers Society Recently Organized

TO PROVIDE a meeting place for standards engineers from all branches of industry, the Standards Engineers Society has been formed, from the year-old Standards Engineers Club.

The society will not create standards but will study philosophy and mechanics of standardization as they pertain to daily work of standards engineers.

Present enrollment includes members of 14 metropolitan industrial firms and professional and trade organizations. Enrollments are being accepted from standards engineers and others interested in standardization. Further details can be obtained from H. R. Terhune, Secretary, Standards Engineers Society, RCA Victor Division, Bldg. 7-4, Camden, N. J.

Recent Advances in Metal Microwave Lenses

NEWEST RADIO WAVE FOCUSING LENSES, which can handle 50 to 100 television channels or tens of thousands of simultaneous telephone messages, have been developed by Bell Telephone Laboratories. These lenses are for radio relay systems connecting large cities: New York to Boston and proposed New York to Chicago. Since 30 miles is the average distant for transmission of microwaves, frequent relay stations are necessary. Transmission is best when beamed as slender ray.

The new lenses are based on theories of light transmission through atomic and molecular structures; one lens is an array of metallic spheres and looks like the popular conception of a crystalline molecule. Radio waves, in passing through the lens, set up electric currents on sphere surfaces and produce the same effect on radio waves that molecular lattices of glass or crystalline lenses produce on light waves.

Microwave lenses are built by scaling-up the molecular lattice structure of a dielectric such as glass, and then substituting electrically conductive elements for the molecules. These elements need not be spheres but can be small strips of conducting material, such as aluminum or copper foil construction.

Early metallic lenses (PRODUCT ENGINEERING, July 1946, Page 136) were constructed of conducting plates and operated on wave-guide principles that increased speed of radio waves as they passed through. Newer lenses slow radio waves as glass lenses slow light waves.

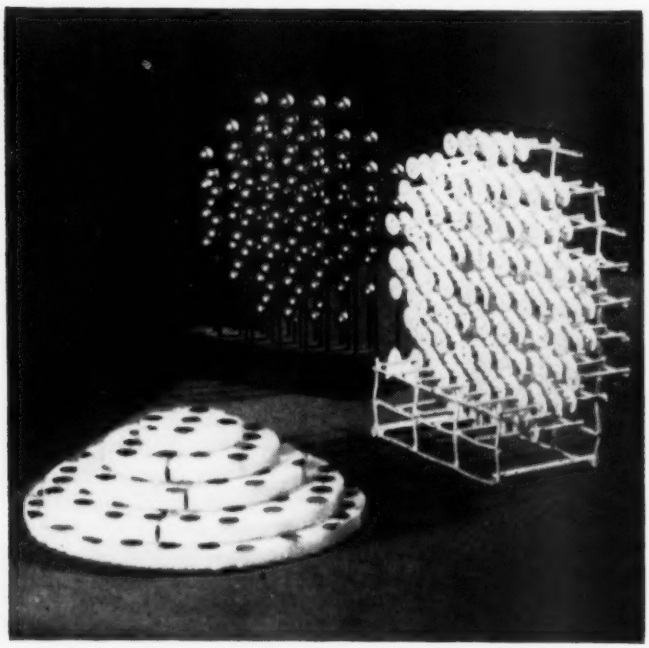
Present lenses are effective for 8 television channels and can only cover the narrow wave length band between 3 and $3\frac{1}{2}$ in. Newer lenses are effective at all microwave lengths between $\frac{1}{2}$ and 4 in., and can handle many more programs.

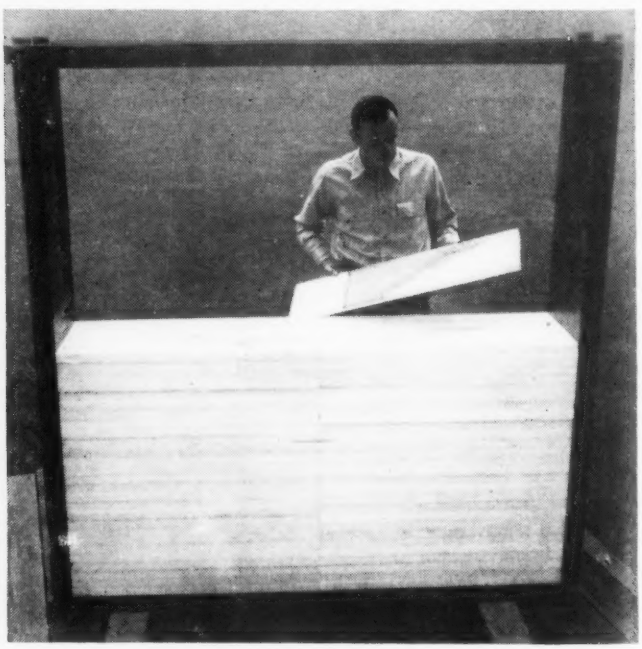
Radio waves are fed through a wave-guide behind the lens, then spread along a horn-like shield into the lens which focuses them into a beam. Beamed waves are received by a similar combination of lens and shield where the reverse operation is performed.

It has been known for some time that glass lenses could focus microwaves just as they focus light waves. But such lenses would have to be big and heavy. A lens of this type would measure 10 ft in diameter and weigh several tons.

Dr. Winston E. Kock, director of the development, reasoned that if lattice structures, which are believed to constitute atoms and molecules, could focus light waves, a scaled-up version of a lattice structure would focus electro-magnetic or radio waves of correspondingly scaled-up wave lengths.

Since microwaves are 100,000 times longer than light waves, a scaling-up in that ratio produces a microwave focusing lens.





Metal microwave focusing lenses, used in radio relay systems, can be made in many forms. Three scale models, at left, show spheres and disks mounted on insulators and disks mounted in polystyrene foam. Optical lens-like shape can be seen in lens being assembled at right. Strips of metal foil are supported in polystyrene foam blocks and assembled in order. Radio repeater lenses are ten feet square.

Washington Notes

Industry Mobilization Plans Progress Rapidly

Masked by overwhelming publicity given to armed services unification under the National Security Act of 1947, little attention has been given to the powerful National Security Resources Board. This Board, headed by Arthur M. Hill and composed of seven cabinet members, is most powerful allocating agency.

The NSRB task is to prepare a mobilization plan, and in time of emergency advise the President concerning coordination of military, industrial and civilian mobilization. It would be the final coordinating agency for allocating industrial potential.

The Military Munitions Board has done most work toward industrial mobilization and NSRB has taken over their first draft of a mobilization plan. NSRB is adding to this plan and is also looking into current problems facing national economy: Fuel, power, manpower and others.

The National Security Resources Board could be a blessing, or it could be a military tool for dominating industry during war. According to the law, however, it is a civilian agency with power to tell the armed services how much of the national economy they can have. If the Board works as it is intended to, and since it ranks the military in chain of command, NSRB should serve to keep the military in line, and stop it from trying to run industry.

The Munitions Board, under NSRB sanction, has started a survey of 11,000 plants, to find out what the plants can do for war production. After all of industry has been cataloged as to plants, products, ability to produce materials, and prime importance to military output, NSRB will decide how much production should be of a military nature.

This Board will avoid the conflicting orders prevalent during the multiple-agency rule during the past war.

Voluntary Allocation Program Encounters Opposition

Petroleum industry's bid for bigger bite of United States steel production ran into opposition from governmnt sources, even before its report—first step towards voluntary allocation of more steel to petroleum uses—was officially approved by the National Petroleum Council.

Report by the special NPC group showed an estimate of steel needed to boost petroleum output by six percent in 1948, five percent in 1949, and four percent in 1950. This estimate is ten million tons of steel per year, or fifteen million tons for the 18 month period beginning April 1.

Assistant Secretary of Commerce David K. Bruce told the congressional committee investigating petroleum and steel shortages that as far as he was concerned, the industry had not yet proved to the government its need for this amount of steel. Sponsors of the steel request are hoping that close examination of figures and basis for them will reveal to Commerce officials that they are not far out of line.

This puts the Department of Commerce, operators of the voluntary materials allocation law, in the position of being asked for allocation programs where they'd rather not have them—and getting refusals from industries in which the government wants allocation programs.

Nitrogen producers, called in to discuss whether they wanted to name an advisory committee to discuss voluntary allocation program for their industry, decided not to name a committee. That is the end of the line under the law. With no voluntary cooperation from industry, nothing happens.

Nitrogen producers seem to speak for all industries in tight supply situations. They see no chance of increasing production through an allocation program and feel the shortages are diminishing.

Since the inception of the law creating long-term material allocations, more industries have refused to have programs than have accepted.

More Strategic Materials To Be Stockpiled This Year

Military planners, taking a long look at the lack of slack in the civilian economy, are seeking a way to get priority or end-use controls over certain strategic and critical materials. Stockpilers have won larger appropriations to put more materials on the shelf this year.

Military factions want ready for

Official U. S. Navy Photograph

Streamlined Subs Go Faster

MOST RECENT STEP toward developing fast undersea craft is shown in the U.S.S. Corporal, one of four submarines being tested in the Atlantic and Pacific oceans. Activated by the United States Navy's "Guppy" program, the Corporal is shown surfaced and its clean lines are evident.

Developed as a result of recent Navy research and based on results of German World War II submarine design, the Guppy class is aimed at raising submerged speeds, range and load.

A second important use of these streamlined underwater speedsters, stripped of all guns and non-essential superstructure, will be to train anti-submarine crews in tactics to be used against modern subs. The Guppy program is the first phase of the Navy's long range effort to design and construct a true submarine, and closely parallels Air Force program to study high speed airplane characteristics.

use on instant notice (and preferably already on the books to be brought into play upon Presidential directive) machinery that will enable them to enforce priorities for the use of these materials. Following claimants would be served in this order: (1) Munitions, (2) stockpile and (3) civilian industry.

Materials on list for this treatment include: Chromite, zinc, cadmium, tin, antimony, bismuth, beryllium, tantalum, manganese, cobalt, vanadium, tungsten, titanium, copper, lead, columbium, lithium, cerium, mica, graphite, corundum, quartz crystals, and others seen on previous stockpile lists.

The armament program would have to enlarge considerably, however, before such priorities would be voted by Congress. Current program, including European Recovery Program shipments, does not put enough strain on the economy to offset antipathy to controls. Hence, military will get materials via dollars, not directives.

While one industry is fighting off military attempts to move in on short supply of metals and materials, another is hoping that war planners will stockpile their materials. Case in point; some distillers, who are talking up the idea of government stockpiling industrial alcohol. The Washington answer: not a ghost of a chance in the foreseeable future.

Report Shows Misuse of Scientists in Wartime

Shortly, there will appear another report from the Army analyzing how scientists-in-uniform made use of their abilities when called into the armed services during World War II. The report will show that about $\frac{1}{3}$ of working, professional scientists were put into jobs where they could not use their technical skills when they were put into uniform. Planners in the General Staff are hoping this report will move generals to act on the obvious proposition: In the next war, the scientist is a primary resource that the military cannot afford to use at less than his maximum efficiency. All statistics of the Army's scientific opinion polls point to wastefulness of taking a scientist, or potential scientist, and running him through Selective Service to produce a foot soldier.

Manpower planners have already started the ball rolling by organizing test groups of scientists who are now in the Army Reserve. First group was organized in Wilmington, Delaware, about a year ago. Others are being activated in large cities, at colleges and at private research organizations.

Another objective is to prevent a situation similar to that prevailing after World War II. Very few potential scientists started or completed educational requirements during the war years—we now have a serious shortage of scientists (see PRODUCT ENGINEERING, June 1947 page 82). At present, draft legislation on Capitol Hill provides no special treatment for scientists.

The Army is not the only activity taking cognizance of this problem. The American Council on Education has advocated national and special control of scientific manpower as a way to give the problem the attention it deserves. Association of Land Grant Colleges is also thinking along these lines. However, there is no unification on the separate proposals. Aside from previously mentioned groups, the Navy is developing a program of its own. Logic of the situation hasn't yet broken down the intra-service barriers.

Depth of Liquid Surface Accurately Measured

SCIENTISTS at the Stanford Research Institute recently announced that they have determined the depth of a liquid surface to be about 1,000 atoms, or approximately one millionth of an inch. The measurement indicates that molecular attraction takes place over a wider range than has ever been proved before. Previous theory held that attraction of surface molecules held to a depth of one-billionth inch.

The discovery can be practically applied in the fields of lubrication, oil exploration and biology, where the reaction of liquid surfaces in contact with other materials is important.

Evidence has been produced that because of the effective long-range influence of molecules upon each other, the strength of a joint depends as much on the strength of the metals being joined as it does on the strength of the adhesive.

The scientists used tiny cubes of copper and tungsten joined together with a thin coat of shellac. With copper cubes, the breaking point of the shellac was 6,000 psi; with two tungsten cubes, the shellac joint broke at 300 psi; and when one of tungsten and one of copper were used, the breaking point increased to 900 lb per sq inch.

Measurements of liquid surface depths are being made at the Research Institute, under Office of Naval Research contract, with an apparatus that measures the distortion of polarized light reflected off the liquid surface.

Long-range molecular influence may be the explanation of a puzzling phenomenon involving the flowing of oil through a slender glass capillary or tube. When the tube is surrounded with water, the oil flows more slowly than when it is surrounded by air.

Heavy Duty Sparkproof Cable

POWER CABLE that will not spark when short circuited has recently been developed, according to the United States Rubber Co. The cable was jointly developed by Leonard Wilson, Kenilworth Mines, Utah, and U. S. Rubber Co. engineers.

The new feature of this cable is a fine copper wire embedded between inner and outer layers of insulation. When the insulation is damaged the fine wire catches incipient current leakage before an arc can occur and carries it to a sensitive circuit breaker that cuts off power.

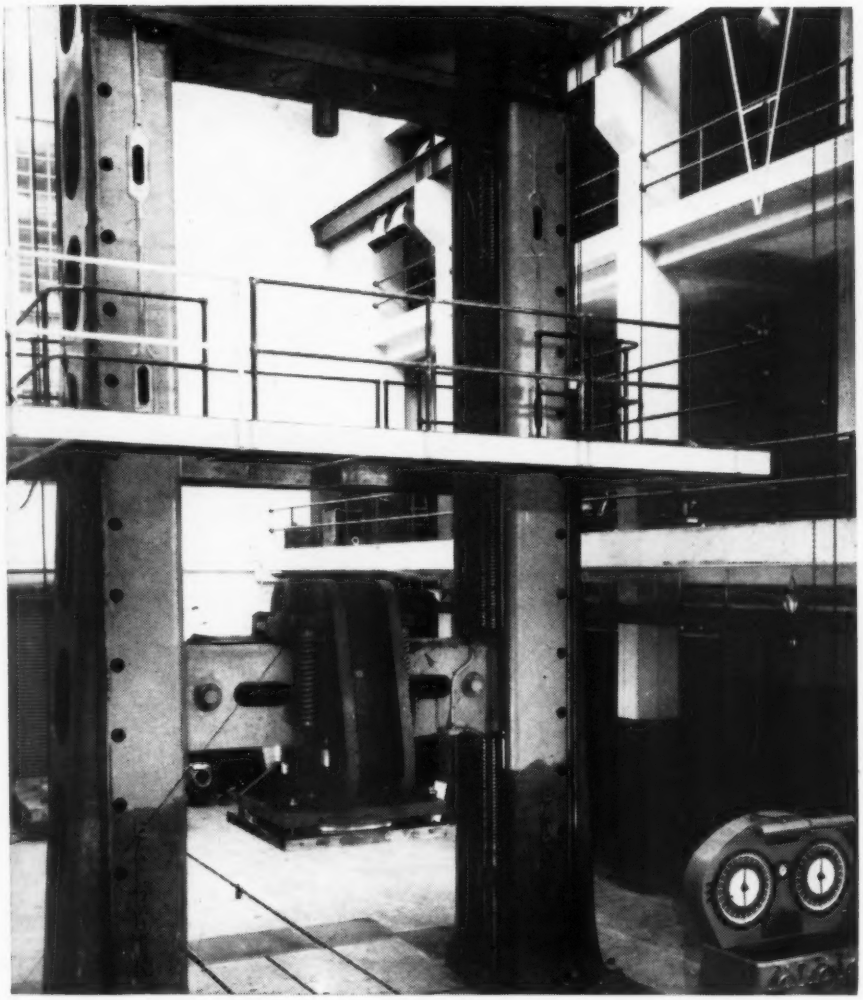
This cable will be initially used to reduce danger of explosions in coal mines. Cables carrying power to heavy digging and transportation equipment drag on the ground, and are in constant danger of being crushed by car wheels.

Additional safety is provided by a new rubber formulation that makes possible colored insulation. U. S. Rubber has made heavy power cable, for mining application, with a highly visible yellow color—a distinct advantage over the carbon-black cables now used. Another example of safety by color.

Plastics Engineers Establish Professional Grade Membership

IN A MOVE to maintain high standards of membership, the executive committee of the Society of Plastics Engineers has established a Professional Grade membership, predicated on 10 years of qualifying experience in the plastics industry.

An applicant having a Ph. D. in science or engineering will be allowed seven years' credit and will therefore need only three additional years of qualifying experience to be eligible for a Professional Grade membership. Similarly, candidates with an M.S. or B.S. degree will be credited with six and four years, respectively. A bachelor's degree from a non-technical college rates a two year experience credit.



CAPABLE OF EXERTING 2,400,000 lb of force, this hydraulic compression testing machine has been installed in Structural Research Lab. of University of Washington.

Rigid Compression Tester More Accurate

A HUGE, HYDRAULIC COMPRESSION TESTING MACHINE, with steel columns more rigid than heretofore possible, giving the machine greater accuracy and making it more versatile, has been installed and recently tested at the Structural Research Laboratory, University of Washington at Seattle.

Special flex-plate construction ties the sensitive yoke to the transverse rigid beam. There are three contacts between the two—the capsule, which acts as a ball bearing and has no vertical stability; the initial load springs, which have no vertical stability; and the flex plates that provide practically no vertical restraint but maximum horizontal rigidity.

Another feature which makes it possible to maintain the minimum tolerance against horizontal deflections under load, to prevent premature buckling of compression specimens and to neutralize horizontal components of force, is flaring of the steel columns from a point about one-third of the distance from the top to the base of the machine. This affords maximum rigidity or minimum deflection when testing specimens so long that their height forces the columns to function as cantilever beams. It is asserted the machine will have from 300 to 400 percent greater rigidity than machines of earlier design.

The university plans to devote the machine to various tests for the timber industry; to testing concrete culverts for the state highway department, and to work for Northwest industries.

The machine will be used for tension and transverse testing as well as for compression tests. It will test specimens up to 10 ft wide, 20 ft high and (for transverse testing) 80 ft long. It is called most advanced universal tester.

The machine can exert a force of 2,400,000 lb, is 37 ft high and weighs 300,000 pounds. It was designed by University of Washington and built by Baldwin Locomotive Works.

MEETINGS

May 31-June 5
AMERICAN SOCIETY OF MECHANICAL ENGINEERS—Semi-Annual Meeting, Hotel Schroeder, headquarters, Milwaukee, Wis.

June 6-11
SOCIETY OF AUTOMOTIVE ENGINEERS — Summer (Semi-Annual) Meeting, French Lick Springs, French Lick, Ind.

June 14-18
AMERICAN SOCIETY FOR ENGINEERING EDUCATION—Annual Convention, Austin, Texas.

June 17-19
AMERICAN SOCIETY OF MECHANICAL ENGINEERS—Applied Mechanics Division Meeting, Illinois Institute of Technology, Chicago, Ill.

June 19
AMERICAN MATHEMATICAL SOCIETY—Meeting, University of British Columbia, Vancouver, B. C.

June 21-25
AMERICAN SOCIETY FOR TESTING MATERIALS—Annual Meeting, Hotel Book-Cadillac, headquarters, Detroit, Mich.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS—Summer General Meeting, Mexico City, Mexico.

June 28-July 1
AMERICAN ELECTROPLATERS' SOCIETY—Annual Convention and Industrial Exposition, Ambassador Hotel and Convention Hall, Atlantic City, N. J.

August 18-20
SOCIETY OF AUTOMOTIVE ENGINEERS—West Coast Meeting, St. Francis Hotel, San Francisco, Cal.

August 24-27
AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS—Pacific General Meeting, Spokane, Wash.

September 13-17
INSTRUMENT SOCIETY OF AMERICA—National Instrument Conference and Exhibit, Convention Hall, Philadelphia, Pa.

September 20-21
AMERICAN SOCIETY OF MECHANICAL ENGINEERS — Aviation Division Meeting, Dayton, Ohio.

September 20-24
ILLUMINATING ENGINEERING SOCIETY—Annual Meeting, Hotel Statler, Boston, Mass.

Foreign Reports from McGraw-Hill World News

A special machine tool made from six standard components, this five-head Renault miller-borer has a rotating positioning table. Rib strengthening of the aluminum transmission-differential housing can be clearly seen on units in the foreground.

Standardized "Special" Machines Highlight Renault Retooling

France's nationalized Renault automobile company (see PRODUCT ENGINEERING, December 1947, page 150) has completed retooling operations needed to start production of the new 19 hp rear-engine car. By standardizing machines to contain six basic units, 55 designers, working with 15 draftsmen, designed 200 special machines in 18 months.

The standard elements are: Three motor units, a transfer slide, a rotating table, a special coolant pump, and a mechanism for halting functioning of certain tools around a rotating table while others continue to operate. After these six components were set, a new machine design needed only base, tool heads and control mechanism details.

Further standardization was effected with the tool heads. Distance between the tip of the tool and the sleeve face is the same in all machines. If new tools are specified during production, the worker can set them without worrying about clearance length.

Most striking novelty, production-wise, is a series of transfer machines for operation on cast parts. Several of these parts, as the illustrated combined transmission-differential housing, are cast in aluminum.

Rough or semi-finished castings are fixed to a bed which is automatically moved along a slide on the transfer machine. The castings stop at several stations where operations of drilling—including step-by-step drilling—reaming, tapping, milling and slitting operations are performed. As a casting moves forward to the next station, a second casting moves up automatically to take its place, the movement of the beds being controlled by toggles. At each station, two or more machine tools, each with one or more spindles, operates on the casting.

The transfer machines are electrically controlled. The control block has a light for each head and each clamp position of the beds on the slide, which winks when breakdown occurs. Special pins at the entry position insure that each bed is entered properly on the slide. Each machine can be stopped by depressing a single button. A separate motor beneath the entry position operates the slide and also operates the slide and also operates a link scraper that collects chips.

Many of the new machines position the parts for the stations by rotation of the table. The table can be set to go through any series of positions, and these need not be in order. Among the 55 multiple head machines of this type, the number of stations varies from two to eight.

A four-head drilling machine, for cylinder blocks, has 42 spindles, including 22 of nearly $\frac{1}{2}$ in. diameter. Cylinder blocks are finished on a 12-station transfer machine with 22 posts. Another cylinder block machine has four stations and six posts but carries 160 tools—55 drills, 55 chamfering mills and reamers, and 50 taps.

An oil pump machine has 12 stations and 19 heads. One transfer machine performs all machining operations on the inlet manifold, a second does the same for the exhaust manifold, and after they are bolted together, a third machine finishes the two—in half the time required for older methods.

Hydromechanics Research Association Formed in G. B.

Leading British manufacturers of hydraulic machinery have recently formed the British Hydromechanics Research Association to coordinate research activities of the several firms and to carry on cooperative research as well.

For the present, the association will gather data on the types of problems confornting members and will make use of university and technical college laboratories for initial research. It will work in close cooperation with the newly established Mechanical Engineering Research Organization, a government-administered activity under the Department of Scientific and Industrial Research, and will probably make extensive use of the MER hydraulic machinery laboratory when it is completed.

Association studies will mainly concern liquid flow within enclosures. It will investigate possible improvements in design and performance of turbines, pumps, valves, heavy presses, and other hydraulic equipment.

Electron-Microscope Developed by Dutch

An electron-microscope operating at 100 kv, with continuously variable magnification from 1,000 to 150,000 times, has been developed recently by N. V. Philip's Gloeilampenfabrieken, Eindhoven, The Netherlands.

A few hand turns of the focusing system produces on the screen an electron diffraction pattern of a part of the specimen that has been selected.

The microscope tube is directed obliquely upward and has a large viewing screen. Details of the image can be examined with an attached magnifying lens. Micrographs, reduced about four times, can be taken on 35 mm film with a camera built into the tube.

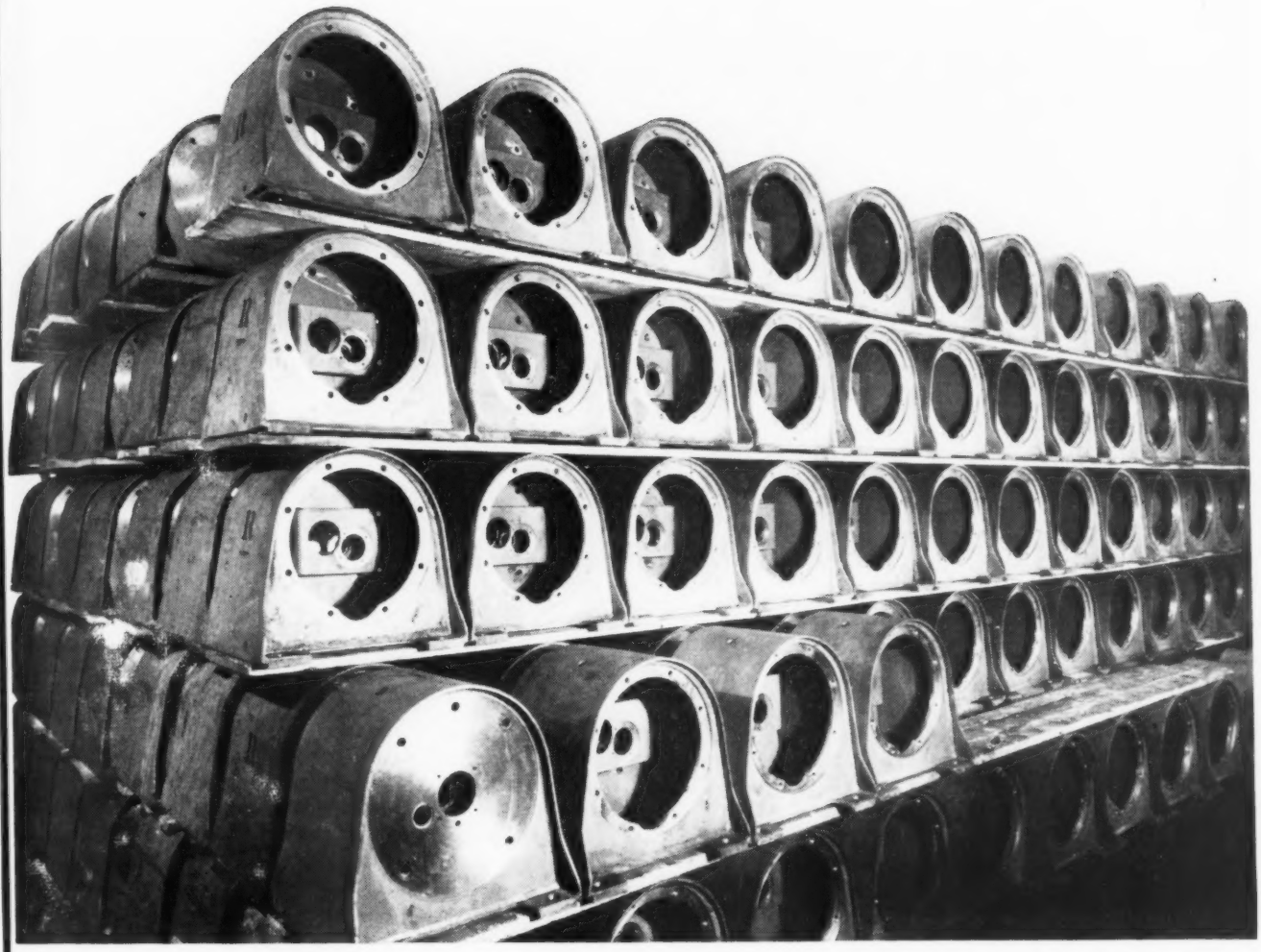


Fig. 1—All-steel housings machined and ready for assembly. Standardization of housing makes volume production possible.

Gear Motors Based on Unit Design

Concentric and right angle shaft arrangements, for both vertical and horizontal driving or mountings, in all-motor and integral types are provided by designing motor gear reducers around a basic unit.

W. P. SCHMITTER
Chief Engineer, The Falk Corporation

LIKE ANY OTHER standardized product, the selection of a gear motor or specially engineered drive can be justified only when it does as good a job and satisfies the needs without appreciable cost penalty. That the development of a line of standard gear motors and speed reducers presents problems that call for the exercise of sound judgment is apparent from the widely varying requirements that must be met. At least 14 factors, each presenting 2 to 4 variations, are involved.

Until recently it was believed that the demands of the field necessitated separate lines of single, double and triple reduction units for both horizontal and vertical operation. Falk made twelve different types of Motoreducers for each size; to obtain them, seven distinct and separate housings had to be manufactured. Moreover, these were supplemented by a paralleling line of speed reducers consisting of twelve different types for each size. The manufacturing problems encountered were reaching insurmountable proportions.

These observations, grouped under their natural headings of direct costs, indirect costs, deliveries and market acceptability, led to some conclusions of an objective nature:

1. Drastically reduce the number of different parts in order to get higher production runs, decrease stocks, and improve deliveries.

2. Increase the volume of standard units and decrease the specials.

3. Provide the best of machine tools, jigs, and fixtures for streamlined production.

4. Reduce handling, trucking, waiting time, and such other indirect costs as contribute to high overhead.

5. Bring more of the materials manufactured into our own plant.

6. Improve performance of the product so as to obtain wider customer preference.

With rapidly rising labor costs, increased ratios of indirect to direct labor, and high break-even point, it became increasingly evident that the

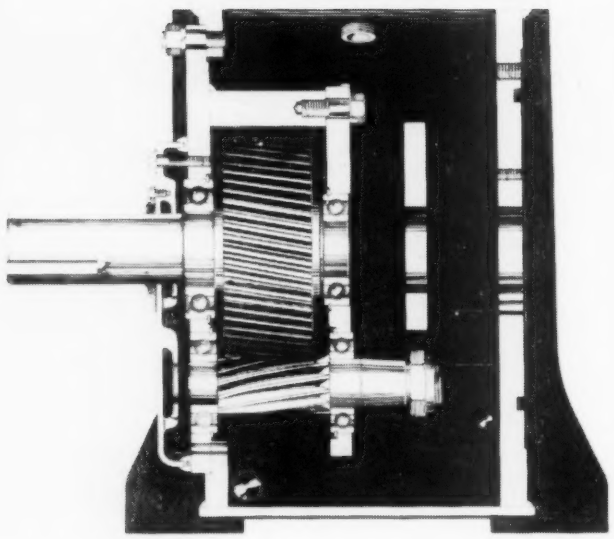


Fig. 2—Main gear set remains unchanged for all ratios. Supporting structure carries radial and thrust loads on bearings.

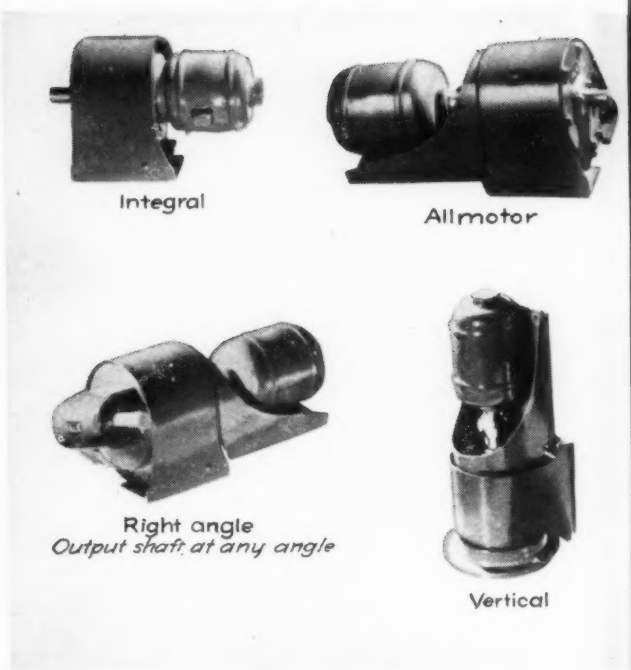


Fig. 3—Basic unit principle is used to meet broad requirements of industrial gear transmissions. The designer's scale models sho

only alternative to increased prices was marked economies in manufacture. The clear cut nature of the objectives contained in the analytical judgment precluded possibility of attaining them without a complete redesign.

The first step in the development of the new line came up almost providentially. A radically new type of welded steel housing was conceived by president Harold S. Falk and in view of the startling advantages it possessed was quickly adopted. It struck the keynote for the entire development—a stronger unit and better engineered for manufacture. The new housing, Fig. 1, consists of an arched cover portion extending over two heavy end-plates having sloping sides, a bottom plate with pads, all machine-welded together to form a structure of great rigidity and strength.

The welded housing met the demand of the public for streamlining. Cast gear housings could only be streamlined by ribbing the interiors, but internal ribs made it extremely difficult to clean out the core sand. There was always the hazard of abrasion of gears and bearings by sand particles, in spite of the extra costs of special cleaning. The new steel housing was the answer, streamlined inside as well as outside.

Another advantage of the welded housing is that it contains no hidden defects that might show up only after considerable processing has been put into the job, as sometimes happens with castings. Thus scrap and salvage costs are reduced. Moreover, the welded housing annually brings thousands of tons of raw material into our own shops instead of semi-finished parts. Thereby we can control availability of the formerly purchased semi-finished parts, the housings, producing them at the rate required from the raw material in stock.

The second concept was that of a basic unit comprising the main cost elements of the transmission and designed to permit subsequent attachments that would satisfy the various field requirements. The basic unit as shown in Fig. 2, could be preassembled in quantities and stocked.

Much effort was expended in the attempt to extend the scope of the standard lines. It was found possible to obtain a degree of universality and adaptability far beyond that previously considered feasible. Projecting the scope of application and taking in more of the fringe areas held out the promise of increased standard unit production, while at the same time decreasing the number of specials and the problems attendant thereto.

Designer's scale models as shown in Fig. 3, were particularly helpful in this effort. All of the combinations shown and several others were adopted for the new line. The line is unique in that it exclusively provides for all-motor and integral types of Motoreducers in concentric and right angle shaft arrangements, and for vertical and horizontal driving or mountings.

All of these variations are had without modifying the stock basic unit from which they are derived. The verticals require only the application of a circular mounting ring and mercury oil seal to the standard horizontal unit. The right angle, Fig. 4, with its unique feature of providing horizontal, vertical or any angle drives, is obtained by the addition of a simple one piece head carrying a spiral bevel gear reduction of advanced design; its space saving possibilities in mounting make it particularly attractive where head room or aisle space is at a premium. The gear-belt Motoreducer possesses similar features, plus the flexibility of the V-belt. A fulcrumed overhead motor with sheaves and belts fitted to the basic unit complete the drive.

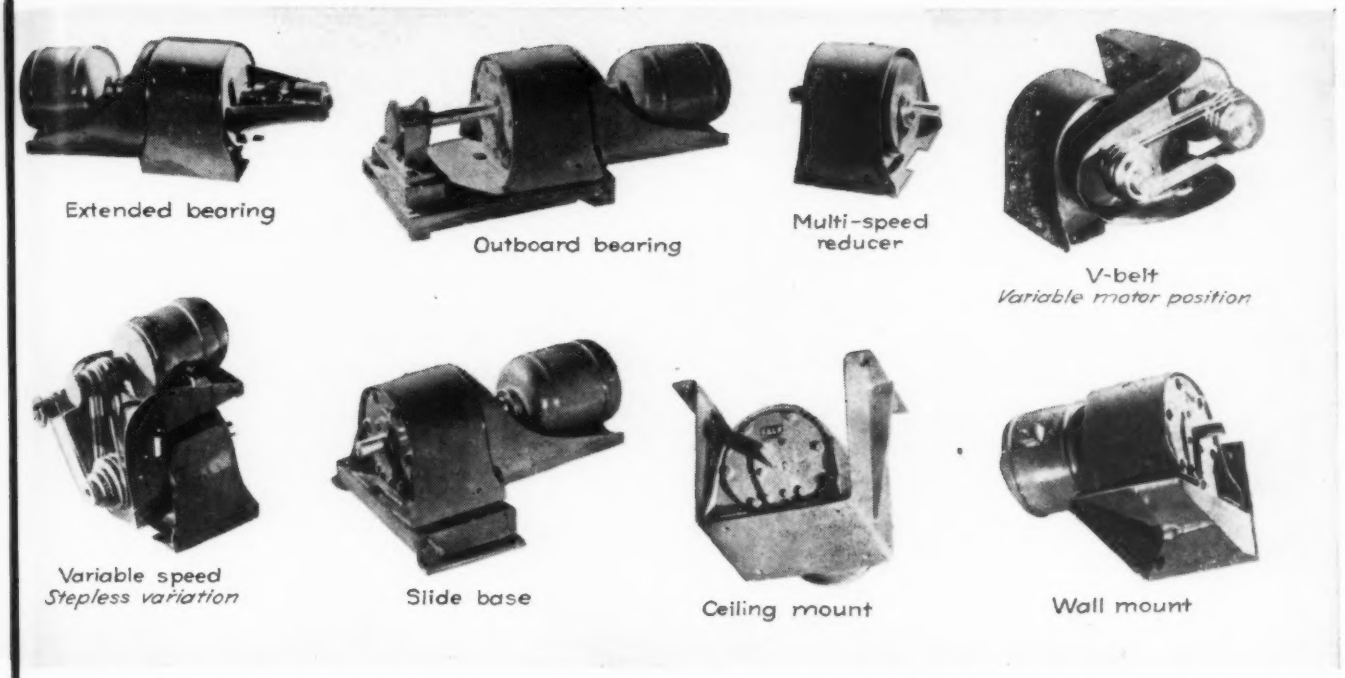
A Motoreducer with steplessly variable speeds, either with or without two-speed head for extended range is included in the line. The outstanding feature of the new multi-speed head is that the speed change is obtained under load without the need of a shifting element. The ratio of ratios ranges from unity up to six.

These various features appeared to meet the needs of the field far better than had been possible with individual designs. The universality of the new gearmotor demonstrates that design can be directed toward sales and still attain other essential objectives.

Drastic Reduction in Parts

Thirdly, came the conviction that we must exploit the possibilities of simplification and standardization far beyond any previous attempts.

The basic unit approach reduced



some of the shaft arrangements and mountings that are easily attained without modifying the stock basic unit. In addition to the combinations shown here a number of other special types were developed for the new line, but not put into production.

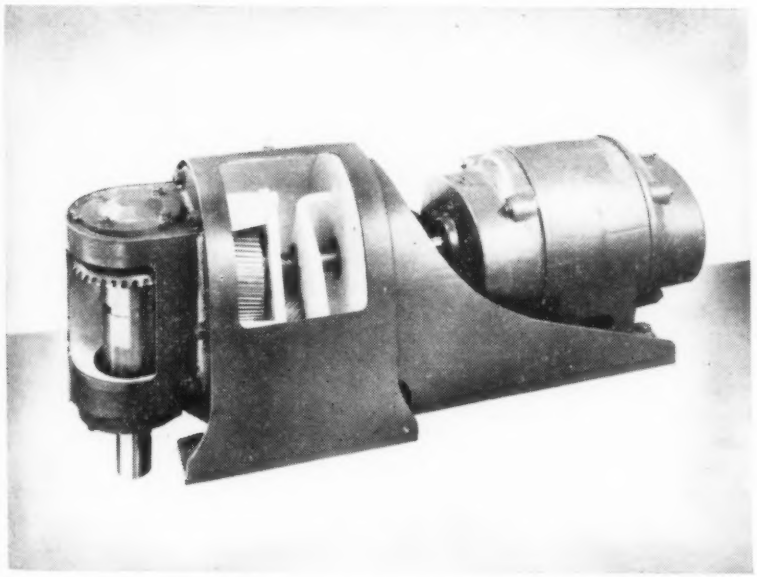


Fig. 4—Right angle drive is made by attaching bevel gear head to standard reducer. Cutaway of test unit shows gears and the bearing mountings.

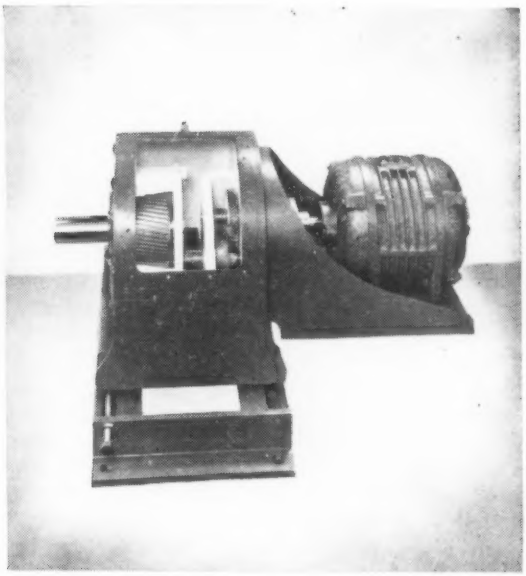


Fig. 5—Four stage reduction unit. Ratios up to 1000 to 1 are available with all standard gears.

the Motoreducer housings from seven to one. Extended studies of the gear elements were eventually rewarded by a reduction to less than half those previously required.

Early in the deliberations the decision was reached to eventually drop the overlapping portion of the existing speed reducer lines and to meet those needs will all-steel reducers derived from the basic unit. The effect on inventories was staggering. One housing replaced nineteen. In place of the 164 gears formerly stocked, 22 now meet all the varied requirements —less than one-seventh of the former quantity. These figures include provision for the right angles and the new quadruple reduction with ratios up to 1,500 to 1—five times the range of the old line.

Equally intensive study was given to the subject of motor brackets. These had previously been designed as part of the housing, either integral with or bolted thereon. This was abandoned in favor of a new plan whereby a bracket was provided for each motor frame regardless of the size of unit on which it would be used. Expensive and unsightly packing blocks were eliminated, the mounting greatly improved, and the total number of brackets reduced from 18 to 11. These could now be jig-drilled to NEMA dimensions, avoiding the need for drilling in assembly.

Engineered for Manufacture

The fourth step was engineering for manufacture. This starts with design but is in no wise limited thereto.

At Falk this activity is handled by a separate department headed by the supervisor of development. His staff includes project engineers and the necessary assisting designers, detailers, and technicians. Responsibilities are

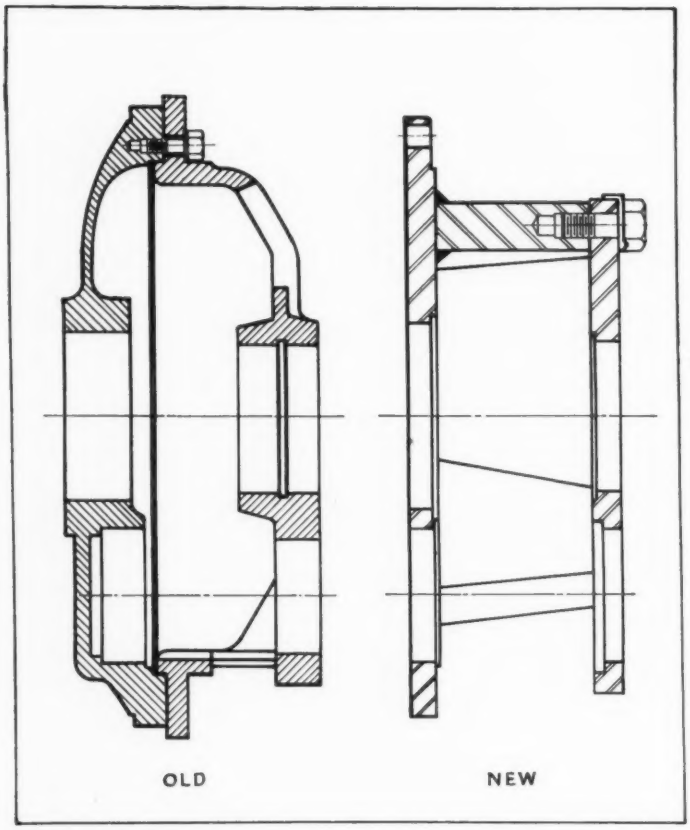


Fig. 6—In new design, cast head and centerpiece were replaced with stronger and lighter welded steel head and bearing plate.

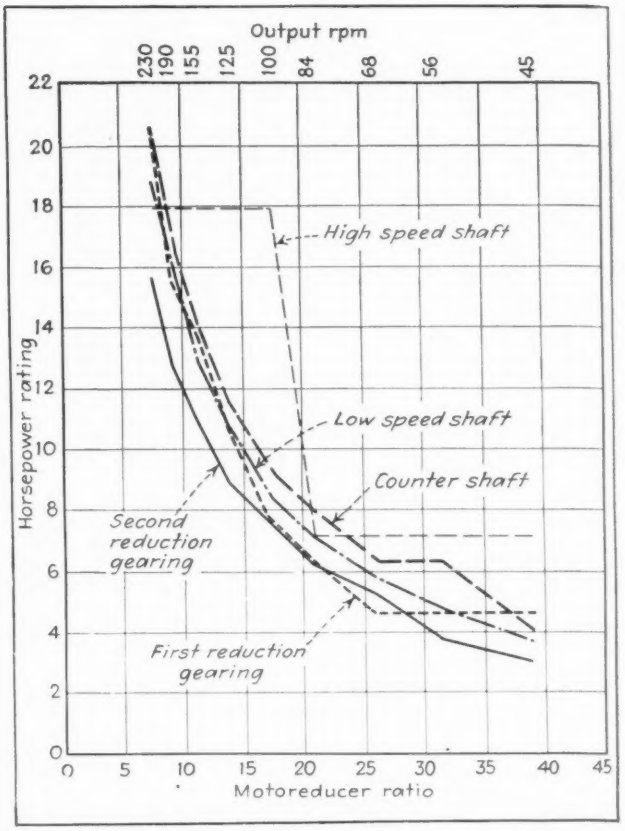


Fig. 7—Horsepower rating for double reduction unit with a 1750 rpm motor. Lowest curve for a ratio determines rating.

not limited to any phase of the operations but include everything down to final testing. But so important a venture as the redesign of a major product seemed to justify supplementing the usual channels with a highly experienced and capable general foreman functioning in a liaison capacity. Weekly meetings with all department foremen were a source of continuing guidance.

To obtain the optimum in manufacturing methods, design must be correlated to fixtures, jigs, machine tools, and even machinery layout. When a product is designed with the necessary consideration given to the tooling, a choice may be made between alternatives, either of which is best adapted to manufacture. Here the tool engineer assumes first line importance.

The program included provision for the latest and best adapted machine tool equipment; multiple spindle drilling and tapping, automatic and semi-automatic lathes, etc. Consideration of the problem of chucking had an important bearing on the decision as to whether gear blanks would be forged or cast.

An example of designing to meet the needs of the shop is illustrated in Fig. 6. The former cast iron head and centerpiece is shown to the left; the re-engineered steel head and bearing plate is shown to the right. The redesign is not only stronger and lighter, but greater precision is also attained. The earlier design necessitated separate machining of the two elements. The new permits complete turning, facing and boring of the assembled structure in a turret lathe. Higher order of accuracy attained is very important, since the main gear contact is involved.

The most spectacular of the new machining processes relates to the all-steel housing. Except for drilling and pre-milling the entire job is done on one machine, at one setting in two-thirds the previous time. The improved accuracy manifested itself in the superior operation of the Motoreducer on the test stand.

Influences of Product Design

One thing that cost figures do not reflect is the savings in overhead when fewer different machines are used in producing the part. Overhead items such as trucking, handling, job card writing, routine, set-up, supervision, and even inspection costs are materially reduced. Further, although perhaps even less tangible, savings arise from the fact that the production flow may be paced to demand, permitting sharp reductions in inventory without adversely affecting delivery schedules.

Only too often little recognition is given to the possibility of saving many minutes all along the line by giving painstaking attention to minor details. For instance, a change from blind tapped holes to through-drilled and tapped holes was made possible by using the new self-sealing studs; the use of modern deburring tools eliminated hand deburring in assembly; the application of plastic coating to gears and pinions for protection while in transit and storage in the shop, prevented their damage. Many similar details could be cited.

Most important of all, the product had to be improved so that it would merit the widest possible customer acceptance, with the hope that a material increase in volume would be attained. The way had been shown in the very beginning of the development stage with the adoption of the all-steel concept. Strength and accuracy were to be the qualities sought throughout. But this matter must be approached with intelligence and prudence. How much of the savings should be put back into the product?

Any line of units which has to meet a large variety of conditions, particularly with respect to ratio demands, must be engineered so that the various component parts not only have

sufficient capacity to withstand the loads encountered, but must, in addition, present a reasonable balance in capacities. Any marked excess of strength which cannot be utilized to advantage by the purchaser in the normal life of a reducer is sheer waste and must come out of the manufacturer's profits. Therefore, the designer attempts to obtain approximately equal ratings in the various component parts. The curves in Fig. 7 illustrate this.

It is impossible for the strength and durability of the various elements to coincide exactly as in the case of the traditional "one horse shay". Indeed, the shafts and gears should be designed to stand up under a severe jam or accidental overload. Except for these considerations, determination of the proportion of parts is primarily an economic procedure.

Speed reducers or Motoreducers are ordinarily manufactured with low speed shaft and bearings adequate to take a certain amount of extraneous loading resulting from sprockets, pulleys or gears. Ordinarily overhung loads are computed and checked against the listed allowables. In the redesign of the large Falk Motoreducer the shaft sizes were increased, which together with larger bearings, made it possible to apply sprockets having diameters only $2\frac{1}{2}$ times that of the shaft, which virtually obviates the necessity for computing the load when quoting on an inquiry. Making it easy to sell by dispensing with the need for engineering computations looked like good sense. Also the added strength gave assurance that breakdowns caused by misapplication will be minimized.

Gear Elements Major Consideration

As is well known, the strength of gearing and also its durability is dependent upon hardness. It is a matter of discretion for the designer, however, to determine which particular hardness is best suited for the design at hand, giving proper weight to both performance and manufacturing cost. The allowable loading on an untreated carbon steel gear is relatively low; while at the other extreme of the range, a case hardened set has a high allowable loading. Untreated gears are excessively large and expensive, while full-hardened gears must be heated and quenched after cutting and are, therefore, subject to certain residual errors. A good solution is obtained with steels heat-treated to a hardness that permits cutting subsequent to heat-treating albeit at reduced speeds and feeds.

Based upon past experiences and tests of gearing of all ranges of hardness, a chrome-manganese-moly steel heat-treated to a minimum of 285 for the gears and a minimum of 335 for the pinions was selected. Excellent ductility and shock resistance is obtained at this hardness with alloy steel. Furthermore, the material retains sufficient plasticity for corrective adjustment of tooth contacts in case of malalignment of the gear elements. It was the considered judgment of the Falk engineers that these advantages offset any slight advantage that might be obtained in the way of apparent lower costs for gears hardened after cutting.

By virtue of the design, which as shown in Fig. 8 limited mating bearing supports to a common structure, high precision, reflected in quietness, absence of vibration, optimum development of tooth contact, and maximum load carrying ability was achieved.

Product engineering is an integrated technological endeavor that is fundamentally economic and commercial. It establishes the base of operations for the life of the design, determines not only direct costs and market acceptability, but influences in major degree, shop procedure, deliveries, inventories, overhead and profits. Intelligent and realistic product engineering leads to highly beneficial results when carried on as an integrated and correlated program that draws upon all of the technological resources of a company.

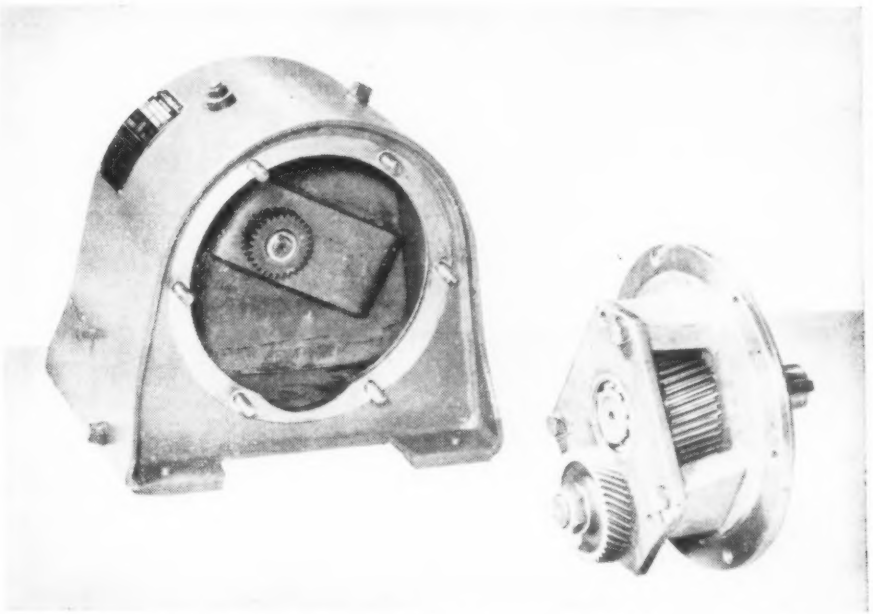


Fig. 8—The all-steel construction provides stiffness on the inside as well as the outside. Main gear elements are bench assembled in precision bored supporting structure.

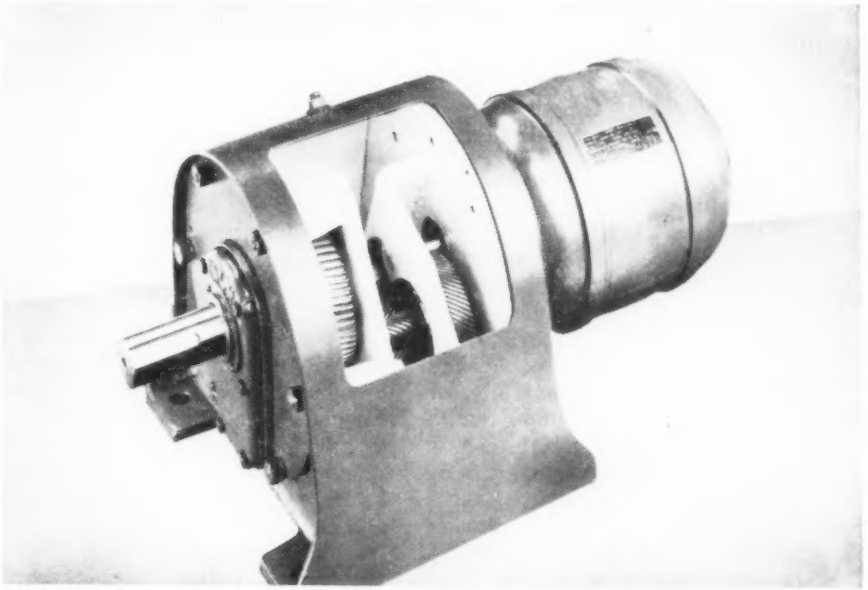


Fig. 9—Cutaway view of triple reduction test unit with integral-mounted motor.

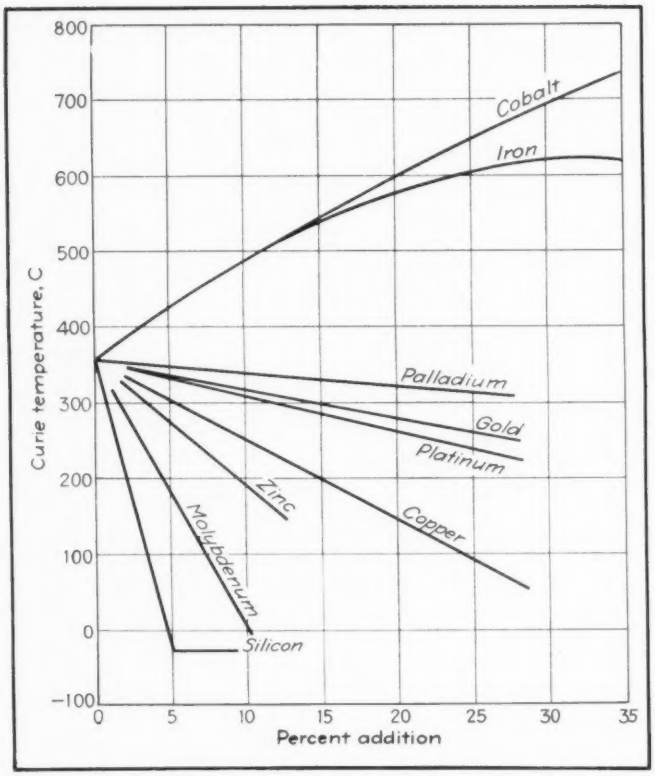


Fig. 1—Curie temperature of various binary nickel base alloys is shown as a function of the percent of the alloying metal added.

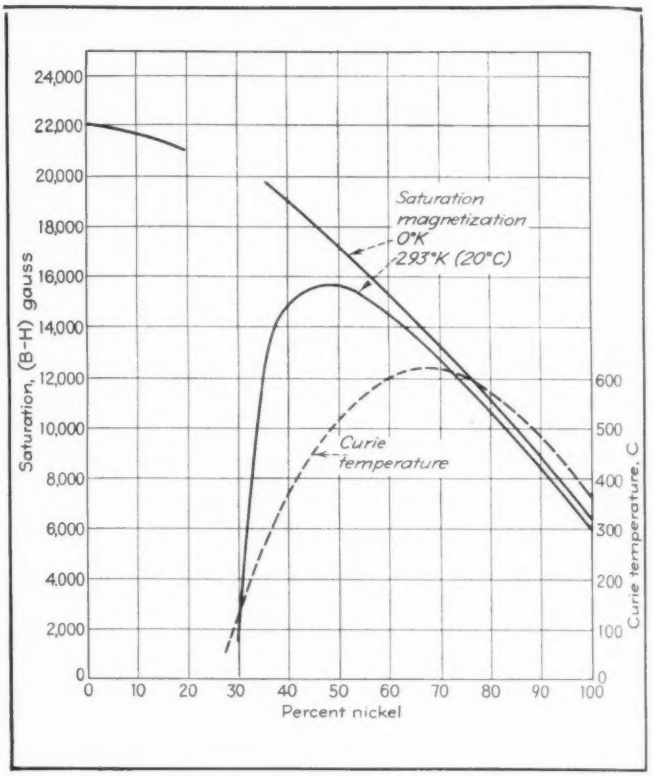


Fig. 2—Curie temperature and saturation as affected by nickel content in the iron-nickel alloys. These are the important alloys.

Curie Temperature Alloys

Explanation of this magnetic characteristic, with data on many alloys. Suggestions for applying the property in mechanical and electrical components.

JOHN SHAW

Research and Development Department
International Nickel Company, Inc.

TEMPERATURE SENSITIVE magnetic alloys offer many desirable properties that have not been widely utilized by design engineers heretofore. However, these alloys have been used extensively in several applications, combining economy with improved performance.

Magnetic materials become nonmagnetic if they are heated above a temperature known as the Curie temperature. The Curie temperature of nickel is 353 C; of iron 768 C; and of cobalt 1,120 C. The addition of a nonmagnetic element, forming a solid solution with one of the foregoing elements, lowers the Curie temperature. By this method it is possible to produce magnetic material having any desired Curie temperature between 1,120 C and absolute zero. The Curie temperature of binary nickel base alloys as a function of percent addition is shown in Fig. 1.[1] It will be observed that addition of more than 5 percent Si has no effect since this is the limit of solid solubility under the conditions of the experiments. Nickel-iron alloys are especially important, particularly between 29.5 percent and 36 percent nickel content. Curie temperature and saturation versus nickel content for these Ni-Fe alloys is shown in Fig. 2 and will be discussed later.

In engineering devices the Curie temperature of the material selected is important in four types of applications:

1. For devices that require strong magnetic properties, the Curie temperature must be well above the highest temperature at which the device will be expected to operate. This is true in units such as motors, generators, transformers, relays, and permanent magnets.

2. A nonmagnetic alloy having strength and other desirable properties of nickel or iron alloys may be required, as in cathode ray tubes, mass spectrometers, armature retaining bands, compass housings, parts of magnetic chucks, transformer bushings, cable sheathing, and certain oil well tools. Here the Curie temperature must be below the lowest operating temperature. These alloys include 30 percent Ni-Cu, 20 percent Cr—80 percent Ni, annealed 18 percent Cr—8 percent Ni steel (if cold work is involved 18 percent Cr—12 percent Ni steel, or better still, 25 percent Cr—20 percent Ni steel is required), "K" Monel*, Inconel*, "326" Monel* and various cast alloys of the austenitic or Ni-Resist* types. Fig. 3 shows the permeability of several wrought alloys as a function of temperature. Equipment in high flying aircraft often gets as cold as —50 C, but in many applications material having a permeability below 1.1 at room temperature is suitable as a "nonmagnetic" component.

It should be noted that the curves

* *Reg. U. S. Pat. Office, International Nickel Co., Inc.*

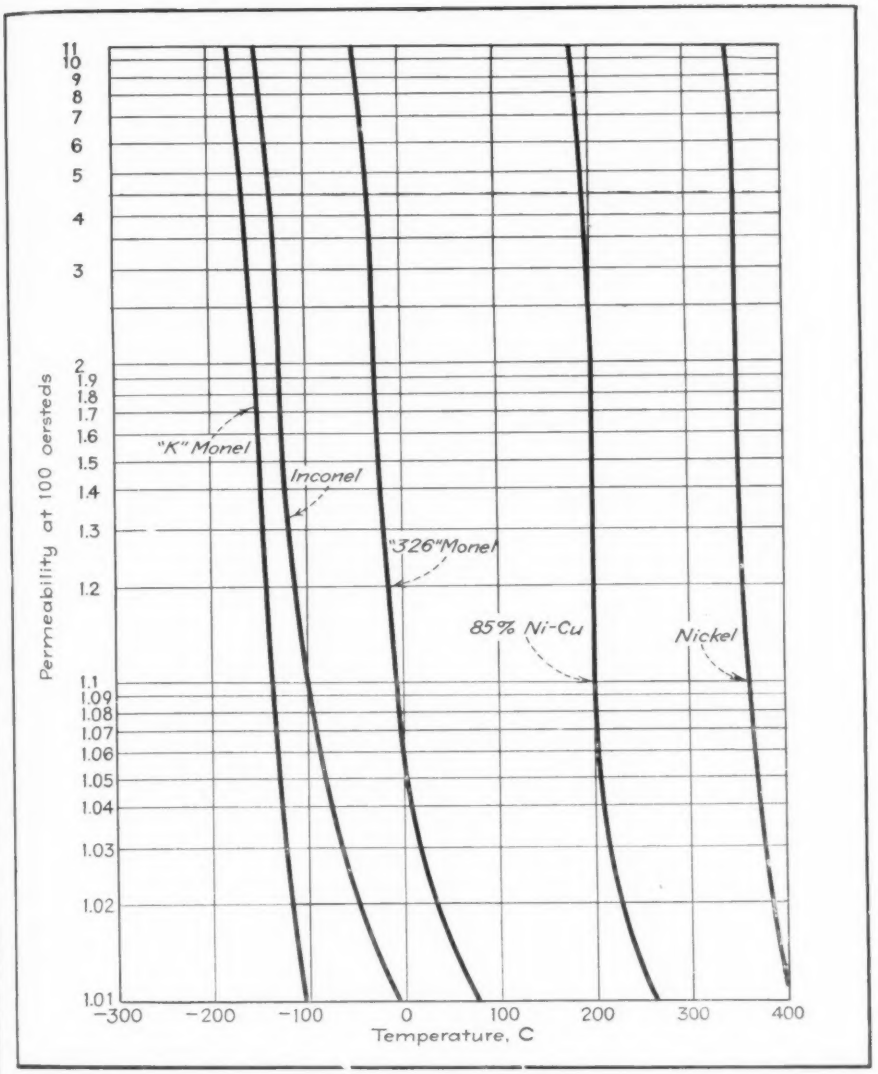


Fig. 3—Showing the permeability of several alloys as a function of their temperature.

shown in Fig. 3, when carried to higher temperatures, never cross the zero axis, but are asymptotic to it. This fact has given rise to many arguments about just what is the Curie temperature of a given alloy. At times engineers have set an arbitrary permeability as the "nonmagnetic" point, and any material with a lower permeability is considered nonmagnetic. Thus for "326" Monel one engineer might consider $\mu = 1.01$ as his limit and call the "Curie point" 80 C. A permeability of 1.1 might be suitable for another application, so here the "Curie point" would be —10 C, or 90 C removed from the first example. In practice, it has been found that the most satisfactory way to define the Curie temperature is to extrapolate the curve to zero. This is done on a linear plot of saturation magnetization versus temperature with a straight line tangent to the steepest portion of the curve. The data shown here are obtained in this manner.

3. It may be desirable to pass through the Curie temperature as in the special expansion alloys for glass-to-metal seals. The extremely low expansion of the Invar class is the result of their magnetic properties. If any alloy of this type is heated, its normal expansion is offset by an internal contraction caused by the progressive loss of magnetism. Upon reaching the Curie temperature this effect is no longer present, and at higher temperatures the alloy expands like normal metals. Fig. 4[2] shows how an alloy of nickel, iron, and cobalt matches one type of hard glass. Other glasses require different alloys having a proper expansion and Curie temperature.

4. This type of application is one that utilizes the change in magnetic properties with temperature. Hence, the operating range of the device will be slightly below the Curie temperature. The remainder of this article will be concerned with this application, as this is perhaps the least known of the four, yet has most design possibilities.

Alloys having low Curie temperatures are useful for temperature compensation, temperature control, and temperature measurement. Temperature compensation of instruments is the most widely used of the three. Control and measurement through the use of this effect are attractive possibilities but have not been developed fully, probably because other methods became established before the Curie temperature method was proposed.

Most of our electrical measuring instruments depend upon a constant magnetic flux in an air gap for accuracy. Proper stabilization of the permanent magnet will insure against loss of magnetism from aging and moderate mechanical shocks. But there still remains a reversible variation of magnetization with temperature. In the laboratory, where the temperature variation is not large and convenience not essential, the meter can be calibrated for a range of temperatures and suitable corrections applied by use of a chart. Generally this is not feasible, notably in the automobile speedometer and the watt-hour meter; therefore compensation for temperature error is required. Sometimes it is desirable to compensate not only for

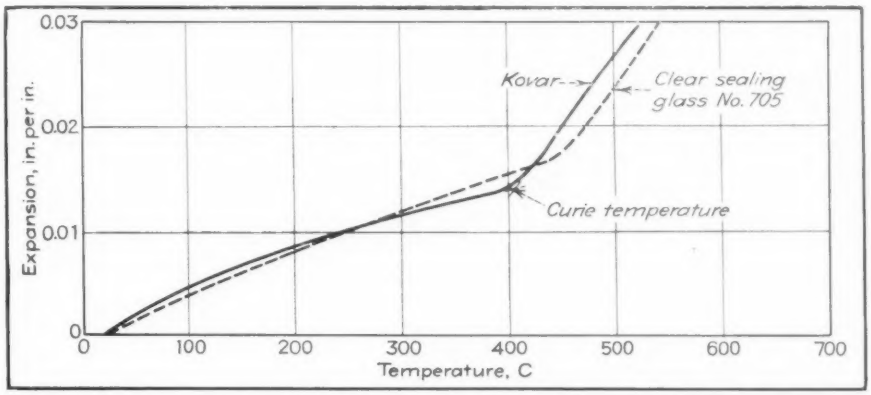


Fig. 4—Curie temperature determines the expansion characteristic of special alloys used in glass-to-metal seals. Other alloys are required to match different glasses.

the variation of the permanent magnet but also for other temperature errors caused by the change in resistance of a winding or drag disk.

A magnetic material does not lose its magnetic properties abruptly at the Curie temperature, but as the Curie temperature is approached, the saturation value decreases in the manner shown in Fig. 5. This curve is characteristic of all ferro-magnetic materials and hence has been plotted on a unit basis. If the Curie temperature and the saturation magnetization of a metal at a single temperature, but preferably at 0 Absolute, are known, the saturation magnetization at any temperature can be readily estimated.

The variation of permeability with temperature is more complex than the change in saturation value, because it is dependent upon the applied magnetic field, material concerned, and previous heat-treatment or cold work. In most applications it is desired to have the permeability decrease with an increase in temperature. To secure this effect it is necessary that the field be adequate to saturate the material. Usually a field of 50 oersteds is sufficient for the commonly used compensator materials. If only a weak field is available a 12.5 percent Mo—80 percent Ni, balance Fe alloy, which will saturate in a low field, can be used. Occasionally, it might be desirable to have an increasing permeability with increasing temperature. In this case a weak field would be used with nickel or a nickel-iron, as Fig. 6[3] shows.

Powder permalloy cores can be compensated for temperature effects by the addition of the proper amount of 12.5 percent Mo—80 percent Ni—7.5 percent Fe alloy powder. This alloy has a Curie temperature of 40 C, and its permeability changes from 9,000 to 1 over the room temperature range.[4]

The most widely used alloy for temperature compensation is a 30 percent Ni-Fe having a Curie point of about 150 C. Nickel-copper alloys (approximately 15 percent Cu—85 percent Ni and also 2.2 percent Fe—30 percent Cu—balance Ni) are also used. These and several other useful alloy systems are shown in Figs. 7[5] and 8. They have been plotted as saturation at 0 Absolute against Curie temperature, the alloy composition being

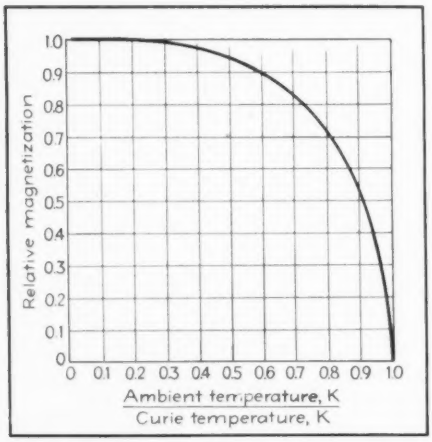


Fig. 5—Characteristic curve for ferro-magnetic materials showing decrease in saturation with approach to Curie temperature.

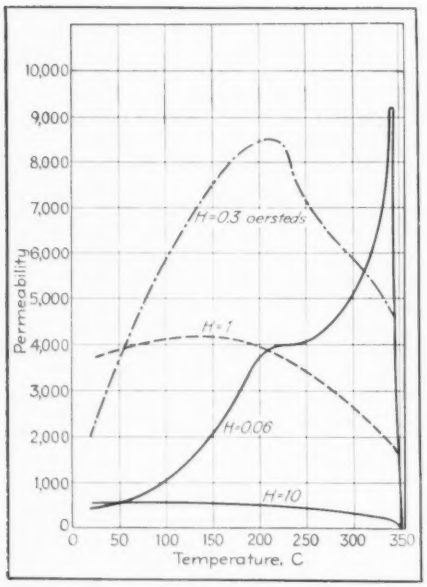


Fig. 6—Permeability of annealed nickel increases with temperature in low fields.

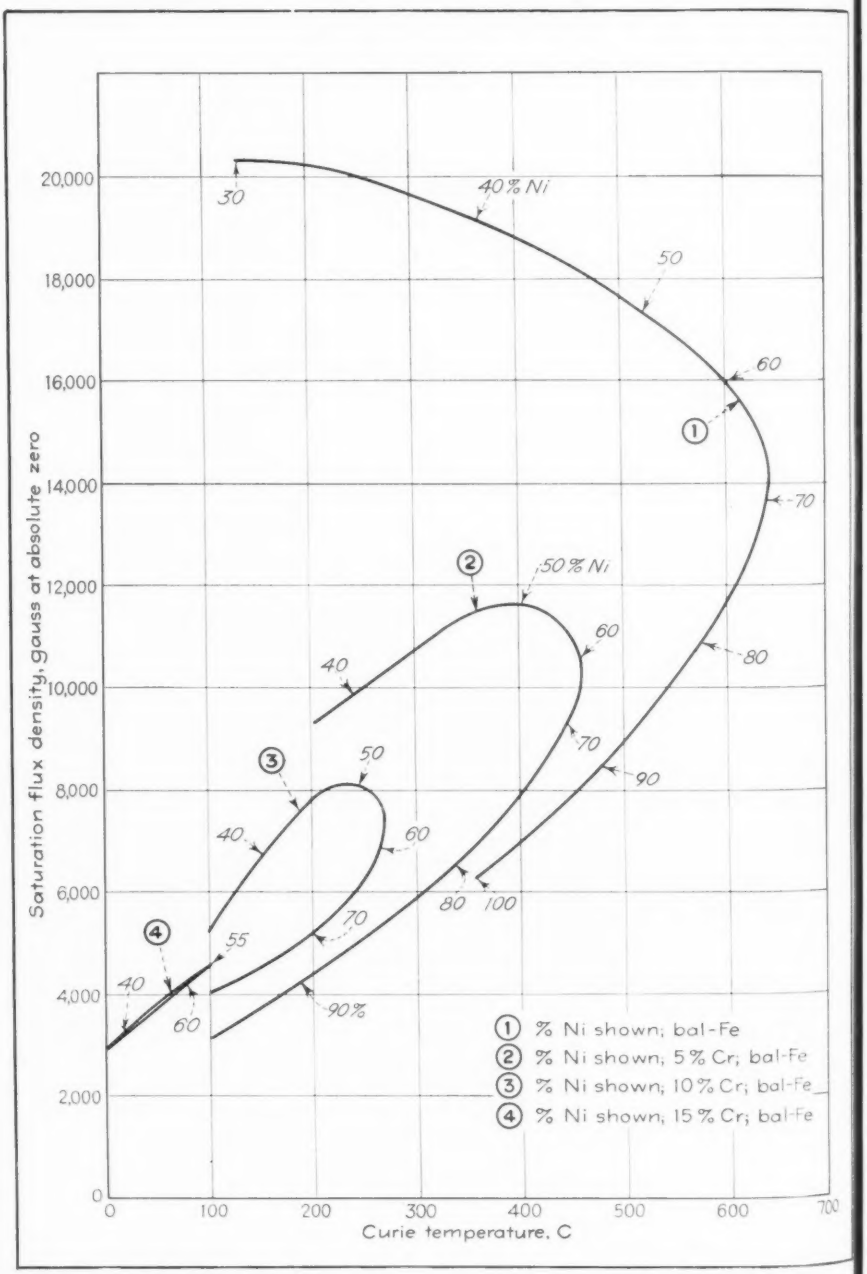


Fig. 7—Graph for comparison of the saturation of several iron-nickel-chromium alloys. Can be used to select an appropriate alloy or to determine a Curie temperature.

indicated along the curve. This is a useful method of comparing different alloys with the same Curie temperature.

The designer will find these charts valuable in either of two ways: (1) If material with a certain flux density at a specified temperature is required, it can be selected from a curve that crosses the desired graph values. (2) If a given alloy is to be used, its saturation flux density is shown throughout a wide temperature range. Aside from specific values at various temperatures, the curves indicate whether the alloy has proper temperature sensitivity for application in mind. Fig. 9 is the permeability curve of the 30 percent Ni-Fe over a temperature range. The slope of this curve can be varied by heat-treatment or by cold work, and in this way it is possible to cause the resultant flux in the air gap of a magnet to remain constant over a range of temperature. It is also possible to cause the flux to rise or fall if so desired. Fig. 10 demonstrates how this is accomplished when a permanent magnet is shunted by a temperature sensitive alloy. Thus, instruments can be temperature compensated not only for a changing permanent magnet, but also for resistance changes caused by temperature.

Watt-hour meters, particularly those placed outdoors, are subject to a wide range of temperature. The mechanism of the meter is essentially a small motor associated with an eddy current drag disk and geared to a counter. The driving torque is proportional to the power consumed by the load, while a counter torque proportional to speed is set up in the drag disk by eddy currents induced by the permanent magnets. Therefore, each revolution of the armature represents a fixed amount of energy and the gear train records this in kilowatt hours. As the temperature of the meter changes, the resistance of the drag disk, the permanent magnet strength, and the resistance of the potential circuit, all change. The composite temperature characteristic of the instrument is corrected by a suitable variable permeability shunt, Fig. 11, as previously described.

A similar application is made to the speedometer or "drag" tachometer, Fig. 12. Here, a permanent magnet

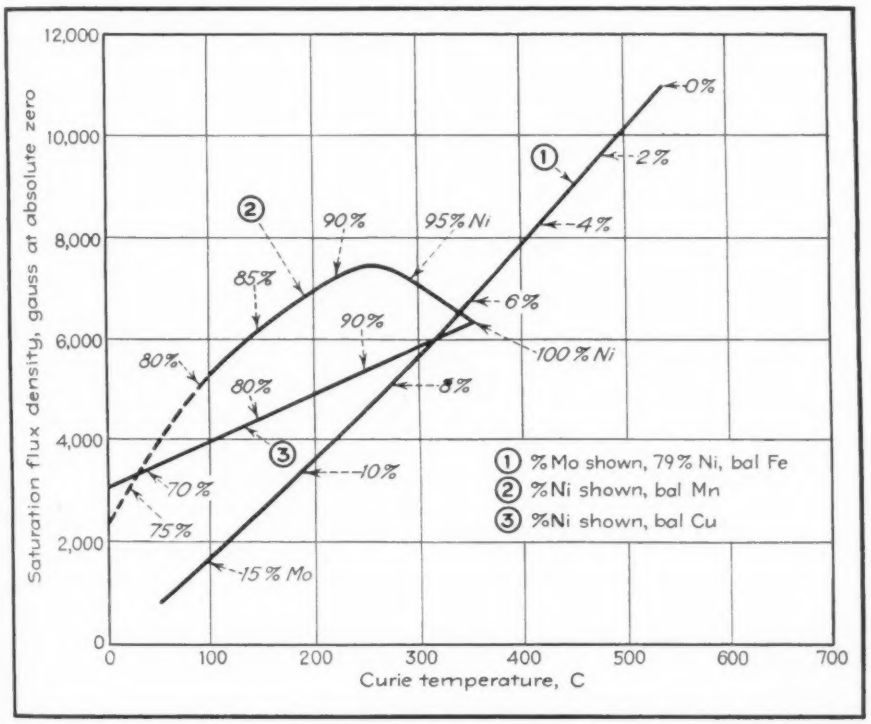


Fig 8—Comparing the saturation of alloys of nickel with manganese and copper.

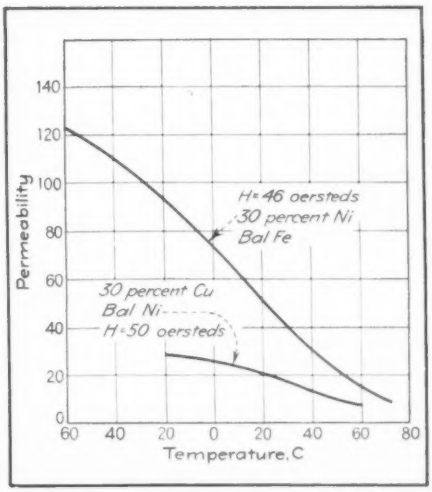


Fig. 9—Permeability curves of 30 percent nickel-iron and 30 percent copper-nickel alloys over the—60 C to 70 C range.

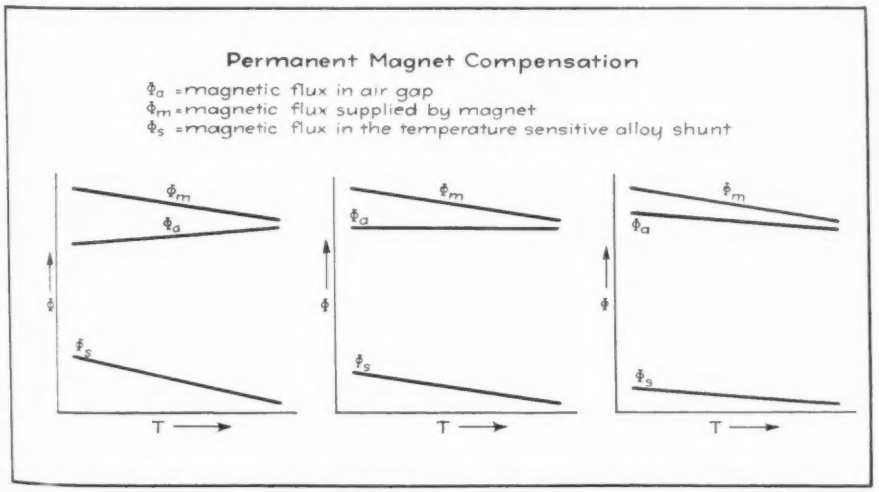


Fig. 10—Three possibilities for varying the magnetic flux in an air gap with temperature change. Curie temperature alloys can be selected to regulate air gap flux as desired.

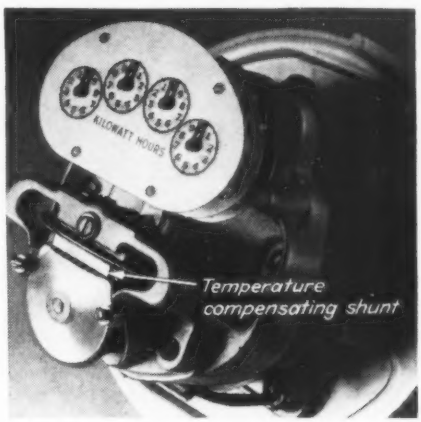
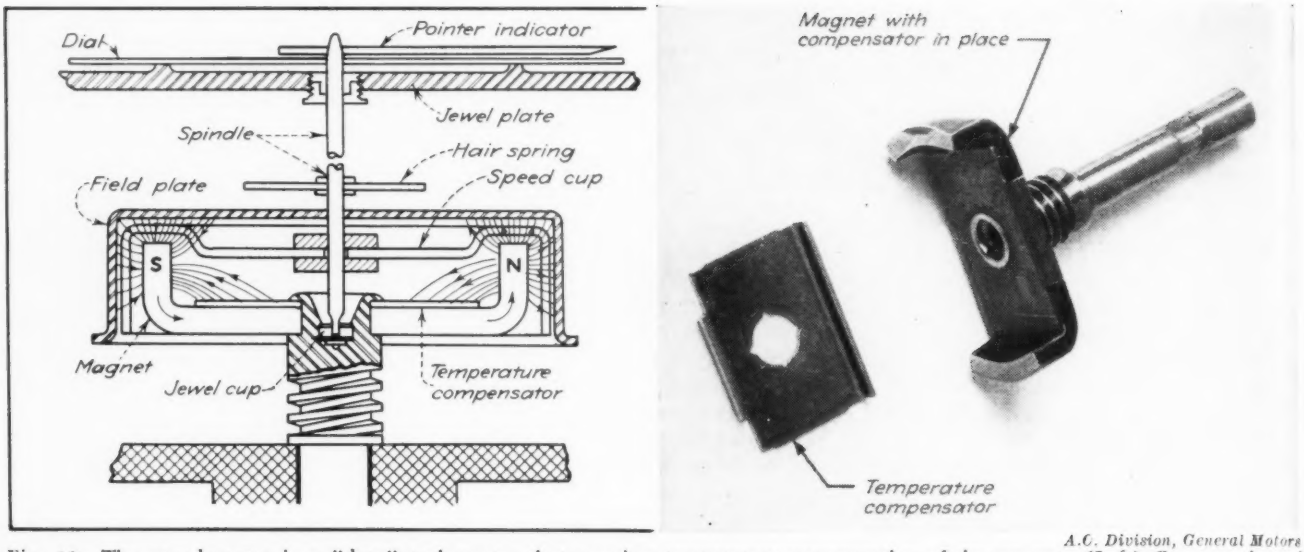


Fig. 11—A strip of temperature sensitive alloy is shunted across the poles of the horseshoe magnet to compensate for permeability changes caused by temperature variation. Shown here a watt-hour meter.



A.C. Division, General Motors

Fig. 12—The speedometer is a "drag" tachometer that requires temperature compensation of the magnet. (Left) Cross-section of speedometer shows construction. (Right) Magnet and compensator shunt. The compensator modifies flux flow in its vicinity.

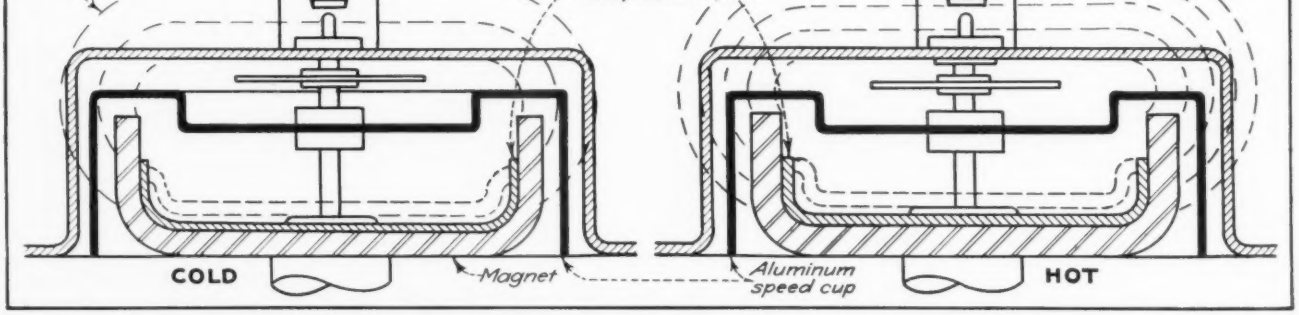
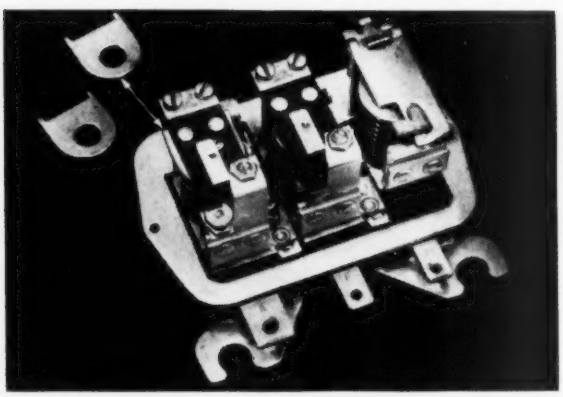


Fig. 13—Temperature effects on magnet strength and eddy current in the aluminum speed cup are corrected by the improved permeability of the compensator shunt as temperature increases. This correction is essential to maintain speedometer calibration.



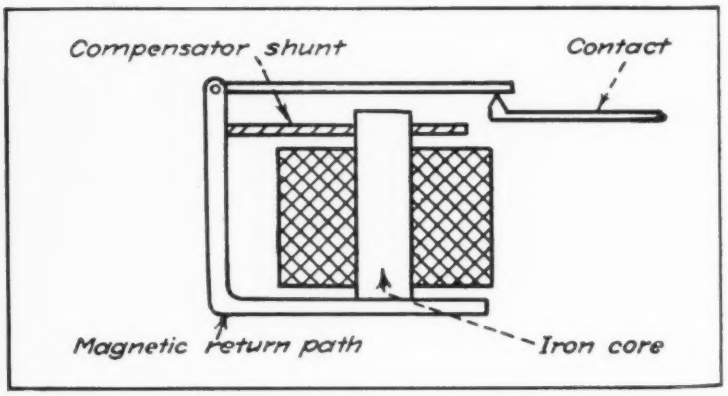


Fig. 14—Automobile voltage regulator compensation to correct the coil magnetism changes caused by the engine heat.

is rotated close to a conducting non-magnetic disk or cup. The eddy currents induced in the disk produce a torque proportional to the speed of the rotating permanent magnet. Rotation of the disk is restrained by a hair spring so the device can be calibrated in mph or rpm, as desired. Temperature errors arise because of changing strength of the magnet and changing resistance of the disk. For example, a speedometer on an automobile travelling 60 mph, reading correctly on a winter day, (0 F) would read 42 mph on the hot desert (120 F). A magnetic shunt, Fig. 13, as in the watt-hour meter, is designed to compensate for both of these effects.

In a similar manner, it is possible to shunt a portion of the flux from an electromagnet, thereby compensating for reduced flux density because of the increase in resistance of the winding with temperature. This scheme is used in automobile voltage regulators where the regulator is near the engine and subject to temperatures through a —40 C to 100 C range. The compensated material is mounted at the end of the magnet core and in contact with the armature return path, Fig. 14. At low temperatures the compensator alloy shunts some

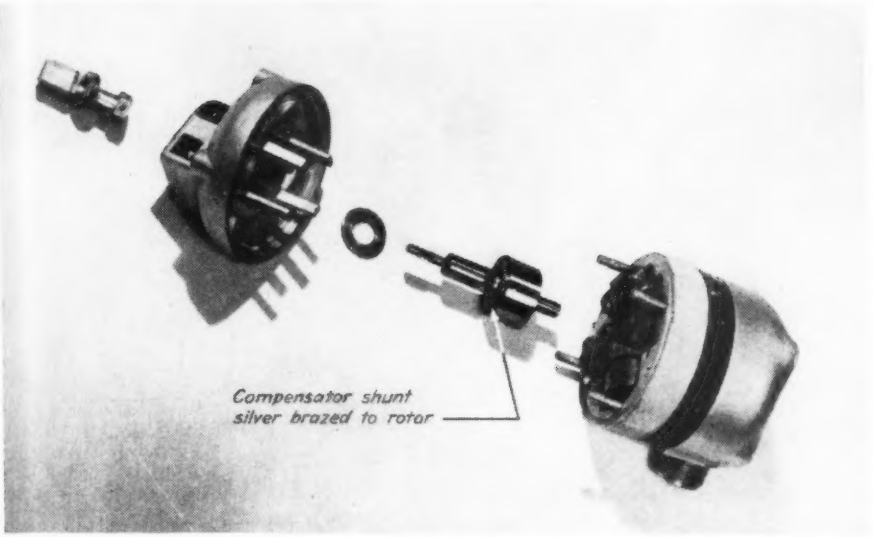


Fig. 15—Temperature compensator shunt is silver brazed to the 8 pole rotor. This tachometer is a dynamo having output voltage proportional to rpm of the shaft.

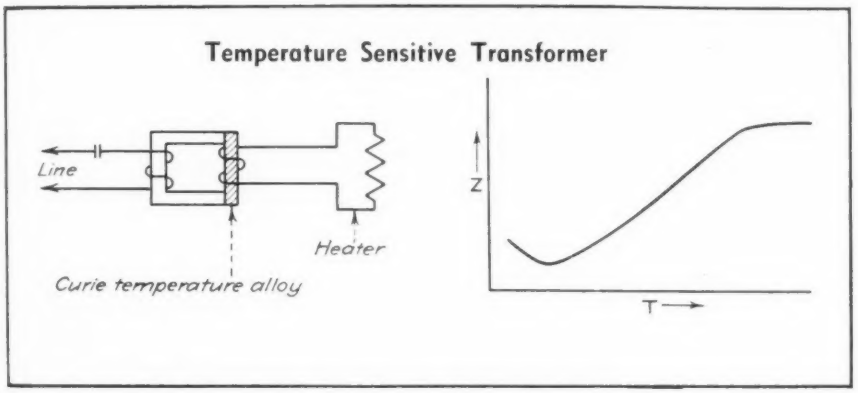


Fig. 16—Temperature sensitive transformer has possibilities for a more even heat regulation, through control of permeability and saturation of the core of the secondary.

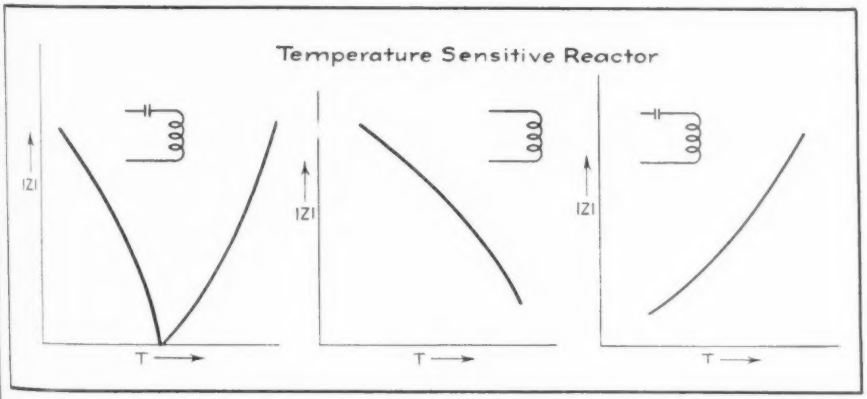


Fig. 17—Temperature sensitive reactors made with desired reactance characteristic.

flux through this circuit, reducing that through the relay armature. For this service, an alloy having a slightly higher Curie temperature than that used for meter compensation is required so that a 32.5 percent Ni-Fe alloy is employed.

An instrument made by the Weston Instrument Company for accurately indicating the speed of rotating machinery is the electrical tachometer. This is a small dynamo that is constructed in such a way that the output voltage is proportional to rpm of the shaft. The armature is a cylindrical permanent magnet, magnetized to have eight salient poles. A disk of 30 percent Ni-Fe is placed at the end of the cylinder, Fig. 15, to keep the flux from the magnet constant over a temperature range.

Temperature control of rooms or ovens can be accomplished by using a bar of low Curie point material as the armature of a contactor. The contactor assembly is placed on the surface or within the volume of the oven to be controlled. At a predetermined temperature, the armature will become nonmagnetic, thereby opening the contactor and shutting off the power. Some adjustment of the operating temperature can be secured by changing the spring tension on the armature. If a greatly different temperature is required, the armature material must be changed. One objection to this device is the "on-off" nature of heating, which applies equally well to other temperature controls.

A method of circumventing the on-off heating effect, and incidentally, one of the few methods of smooth heat control, is to make one leg of a transformer core of an alloy having the desired Curie temperature as shown in Fig. 16. The transformer is placed within the region to be controlled and the secondary connected to the heater element. A capacitor is placed in series with the primary to obtain a rising impedance curve. As the temperature of the vessel increases, the permeability and saturation of the core decreases; thus less power is transferred to the secondary. In addition, the impedance of the input circuit is increasing, accentuating this effect. An equilibrium value will be reached where the heat loss of the vessel is just equal to the power supplied to the heater. Where it is necessary to control large amounts of power, a magnetic amplifier might be used in conjunction with this device. In the same way a temperature sensitive reactor, Fig. 17, can be constructed. In combination with a capacitor it is possible to have a rising or falling reactance characteristic or to pass through resonance at desired temperatures.

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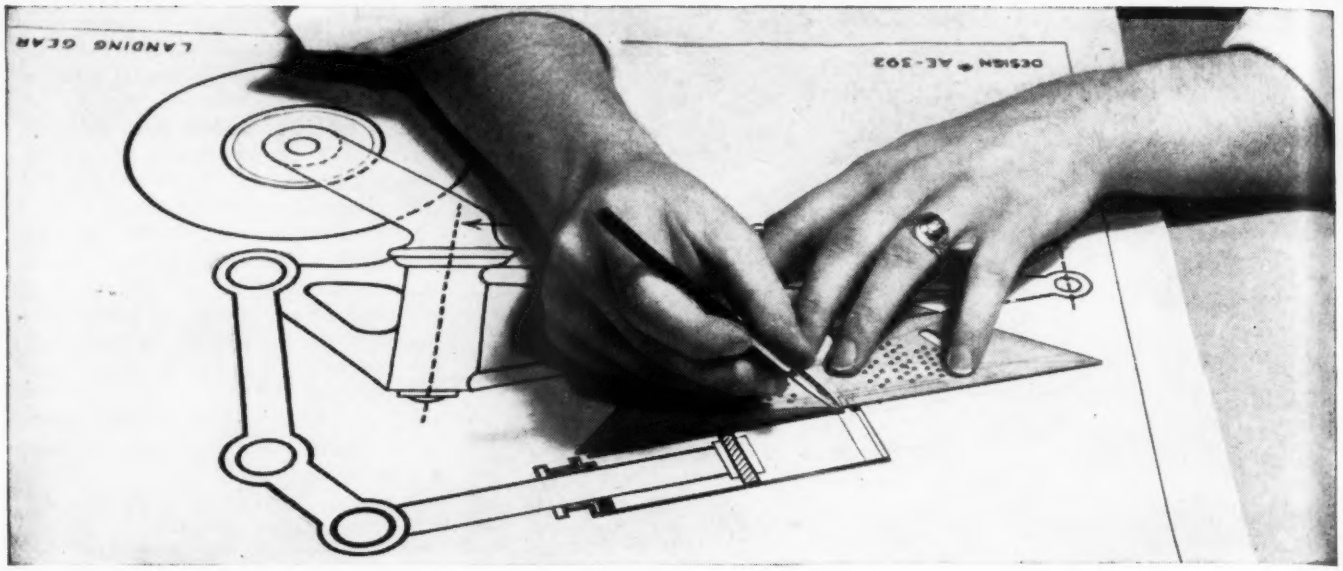
2. Fig. 4—H. Scott, *Journal Franklin Inst.*, Vol 220, p 733 (1935).

3. Fig. 6—Derived from Don Kirkham, "Variation of the Initial Susceptibility with Magnetization, and the Variation of the Magnetostriction and Reversible Susceptibility with Temperature and Magnetization in Nickel," *Physical Review*, Vol 52, No. 11, Dec. 1, 1937.

4. V. E. Legg, "A Survey of Magnetic Materials and Applications in the Telephone System," *BSTJ*, July 1939.

5. Fig. 7—Derived from L. R. Jackson and H. W. Russell, "Temperature Sensitive Magnetic Alloys and Their Uses," *Instruments*, Vol II, Nov. 1938, pp 280-282.



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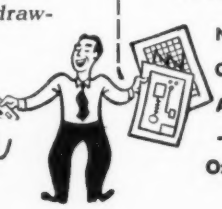

Thickness Standards for Cadmium Electroplate

GEORGE BLACK

THE VALUE of cadmium plated coating was completely demonstrated during the war years. Their high resistance to atmospheric corrosion, and their similarity in potential to the various aluminum alloys made them the standard for steel, brass and bronze parts used in aircraft. Their excellent resistance to alkalis has made them invaluable for washing-machine parts, steel shapes set in concrete, etc. Cadmium is easily and rapidly applied with a minimum of "controls." Specifications are listed of thickness requirements for commercial deposition.

1. AMERICAN SOCIETY FOR TESTING MATERIALS

Designation: ASTM A165-40 T
(Prepared jointly by American Electroplaters' Society, National Bureau of Standards and the American Society for Testing Materials)

Type	Minimum thickness, in.
N. S.	0.0005
O. S.	0.0003
T. S.	0.00015

Note 1: The designations "N", "O" and "T" were chosen arbitrarily; "S" stands for steel base.

Note 2. These thicknesses refer to significant surfaces only, which are defined as surfaces that are visible and subjected to wear or corrosion, or both. It is recommended that these surfaces be designated on blueprints.

2. ARMY-NAVY AERONAUTICAL

Designation: AN-P-61-2

Type	Minimum thickness, in.
General purpose	0.0003
Threaded areas	0.0002
Bolts, nuts, studs, etc., the major portion of which is threaded	0.0002

Note 1: No requirements are established for holes, recesses and other areas where a controlled deposit cannot be obtained under normal plating practices.

Note 2: Thicknesses listed are "final thicknesses", as determined after passivating, corrosion inhibiting and/or paint adherence treatments have been concluded.

3. AERONAUTICAL MATERIAL SPECIFICATION

Designation: AMS 2400 E
(Prepared by the Society of Automotive Engineers)

Type	Thickness, in.
For general purpose	0.0003-0.0005
For threaded sections	0.0002 min.

Note 1: To specify any thickness other than the general purpose and threaded section designations listed above, add a suffix number that indicates the minimum thickness desired.

Example:
AMS 2400-1 indicates thickness between 0.0001 and 0.0003.
AMS 2400-6 indicates thickness between 0.0006 and 0.0008.

Note 2: Tolerance of plus 0.0002 in. is considered standard.

Note 3: Threaded surfaces may be 0.0001 in. under minimum.

Note 4: No requirements are established for holes, recesses and other areas where a controlled deposit cannot be obtained under normal plating practices.

4. NAVY DEPARTMENT

Designation: 46-P-1

Type	Minimum thickness, in.
General purpose	0.0005
Parts threaded externally	0.0002

Note: Thickness requirements shall be met on smooth surfaces which constitute neither decided prominences nor recesses.

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- To Army-Navy Specification AN-J-C-48-A copper conductor

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- Copper conductor to Specifications AMS-3390, AMS-3392 and commercial standards

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- To Army-Navy Specification AN-J-C-48-A copper conductor
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- Wiring Assemblies

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Thickness Standards for Zinc Electroplate

GEORGE BLACK

ZINC was one of the most used plated coatings during the war for protection against corrosion. In general, zinc plate protects steel against corrosion as well as cadmium plate, but forms bulky white corrosion products more readily. Zinc is anodic to aluminum and its alloys and electroplated zinc protects the base metal under certain corrosive conditions. However, if other metals are plated over the zinc, the plate may crack or peel. Zinc plating is used on parts where the less expensive dipping techniques would not give the proper coating. Listed are the specifications now existant which cover thickness requirements for commercial deposition.

1. AMERICAN SOCIETY FOR TESTING MATERIALS

Designation: ASTM A 164–40T
(Prepared jointly by the American Electroplaters' Society, the National Bureau of Standards and the American Society for Testing Materials)

Type	Minimum thickness, in.
G. S.	0.001
L. S.	0.0005
R. S.	0.00015

Note 1: The designations "G", "L" and "R" were chosen arbitrarily and "S" stands for steel base metal.
Note 2: These thickness refer to significant surfaces only, which are defined as surfaces which are visible and subjected to wear or corrosion, or both. It is recommended that these surfaces be designated as blueprints.

2. ARMY-NAVY AERONAUTICAL

Designation: AN–P–32a
(Approved by joint action of the War and Navy Departments)

Type	Minimum thickness, in.
General purpose	0.0005
Externally threaded portions of articles and items such as bolts, nuts, studs, etc., having the major portions externally threaded	0.0002
External parts of seaplanes or amphibians	0.0010

Note 1: No requirements are established for holes, recesses and other areas where a controlled deposit cannot be obtained under normal plating conditions.
Note 2: Thicknesses listed are "final thicknesses", as determined after passivating, corrosion inhibiting and/or paint adherence treatments have been concluded.

3. AERONAUTICAL MATERIAL SPECIFICATION

Designation: AMS 2402B
(Prepared by the Society of Automotive Engineers)

Type	Thickness, in.
General purpose	0.0005–0.0007

Note 1: To specify other plate thickness, add a suffix number designating the minimum thickness in thousandths of an inch. A plus tolerance of 0.0002 in. is understood.

Example:

AMS 2402–1 designates a thickness range from 0.0001 to 0.0003 inches.
AMS 2402–6 designates a thickness range from 0.0006 to 0.0008 inches.

Note 2: AMS 2402–1, –2, –3, –4 shall not be specified except for parts whose dimensional tolerances will not permit the specification minimum of 0.0005 inches. For such parts, the thickest plate permitted by the tolerance shall be specified.

Note 3: Minimum tolerances apply to all surfaces of parts except externally threaded parts where permission is granted for thicknesses 0.0001in. less than the minimum.

Note 4: No requirements are established for holes, recesses and other areas where a controlled deposit cannot be obtained under normal plating conditions.

4. NAVY DEPARTMENT

Designation: 46–P–2

Type	Minimum thickness, in.
General purpose	0.0005
Externally threaded articles	0.0002

Note: Thickness requirements shall be met on smooth surfaces which constitute neither decided prominences nor recesse

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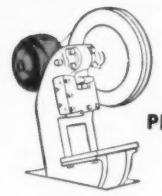
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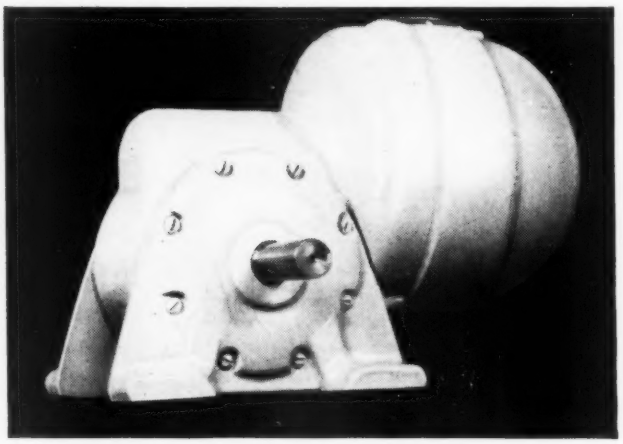

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Electro Motors, Inc., 1110 *N. Lemon St., Anaheim, Calif.*

A fractional horsepower a-c motor and right-angle, single reduction, worm-gear speed reducer have been combined into a compact, lightweight gearmotor. It is manufactured in two models—Foot Mounted (Series 400) and Ring Mounted (Series 500), for 3, 2, and single phase a-c operation, in $\frac{1}{4}$, $\frac{1}{3}$, $\frac{1}{2}$ and $\frac{3}{4}$ hp sizes. All are of the general purpose, continuous duty type, with ball and tapered roller bearings. Motor can be assembled in any one of four positions and the entire unit can be operated at any desired angle. In the Ring Mounted model, a positive seal prevents gear oil from leaking into mixing chambers or other equipment. A wide range of speeds is offered.

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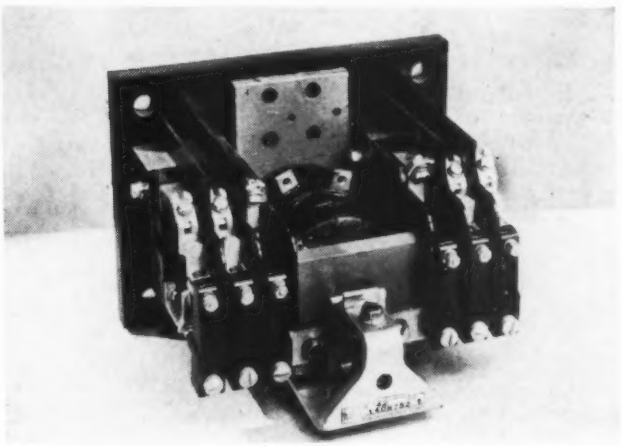
Possessing a high negative temperature coefficient, Thermistors are sensitive to temperature variations as small as 1/1000 of a degree Centigrade. The units are made from a mixture of semi-conducting metallic oxides and are available in the form of rods, disks and beads. Since they are pure electrical resistances, they can be used with either a-c or d-c current. Actuation can be either by ambient temperatures or by internal heating of the element. The negative resistance coefficient of the material can be utilized to offset the positive coefficient of a conventional conductor. These characteristics make Thermistors adaptable to many uses including sensitive elements in flow meters, time delay relays, switches, indicators, controls, meters and other circuit components to correct errors caused by extreme temperature conditions.



Heavy Duty D-C Relay

Westinghouse Electric Corp., 306 *Fourth Ave., Box* 1017, *Pittsburgh* 30, *Pa.*

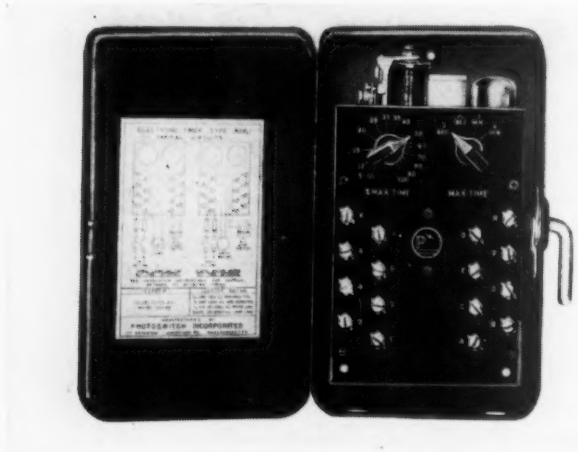
The AYB heavy duty, multipole, d-c magnet operated relay is designed for operation on 600v and below. All contacts are double break, silver to silver; will carry 10 amp continuously at rated voltage and have a maximum interrupting capacity of 150 volt-amp. Inductive coil load is 0.65 amp at 230 volts. Contacts have a fast drop-out when the coil is de-energized. Relay is available in 4, 6, 8, 10, 12 or 14 pole combinations, normally open and/or closed. To prevent overloading the operating magnet, not more than five normally closed contacts should be used in the combination. A mechanical interlock assembly is available for connecting two relays side-by-

side and on the same horizontal centerline. The AYB relay is ideal for use on machine tools, and for other heavy duty applications requiring interlocking of circuits.

Small Fan Motor

Heinze Electric Co., Lowell, Mass.

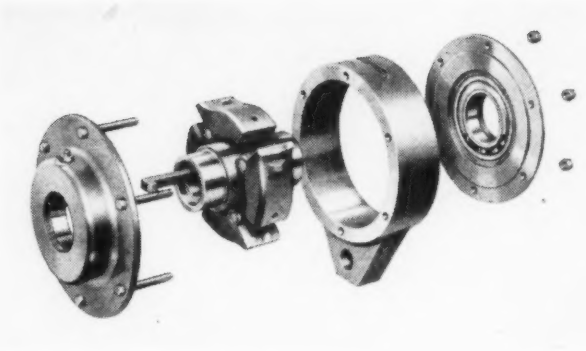
Type z four pole, shaded pole induction motor is 3¼ in. in diameter and suitable for driving 6, 8, 10 and 12 inch fans and small blowers. Ratings range from 1/100 to 1/40 horsepower at a load speed of 1550 rpm on 115/230 v, 50/60 cycle current. Motor can be furnished with ventilated or non-ventilated pressed steel case with or without junction box. Hardened steel shaft can be single or double extension and thrust bearings can be supplied for vertical operation.



Electronic Interval Timer

Photoswitch Inc., 77 Broadway, Cambridge 42, Mass.

Designed for machinery and process control, electronic timer covers the range from 0.03 to four minutes. Unit can be wired to provide interval timing, delayed action, automatic repeat and programming. Single purpose timers combining one or more of these functions are also available. Basic circuit is self-compensating for changes in line voltages. Two single-pole, double-throw relay contacts have ratings of 10 amp (main output), 1 amp (auxiliary), 115v a-c. Ambient temperature range is 32 to 150 F. Operation is from 115/230v, 50/60 cycle current.



Reverse Rotation Stops

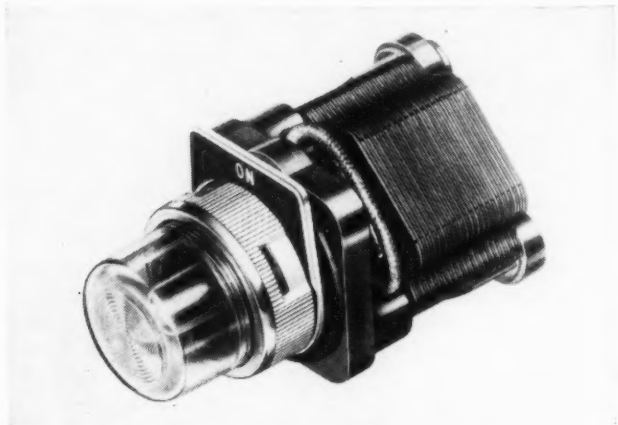
The Falk Corp., Milwaukee 8, Wis.

Protection against damage from reverse rotation of machinery is provided by this positive acting Backstop. The wedging action of the cylindrically machined, spring loaded pawls against the housing bore prevent reversal as soon as normal rotation ceases. Direction of operation can be quickly changed by reversing the rotor-pawl assembly that has keyways with opposite tapers. Specifications for three basic sizes fall within the following ranges: maximum speed, 3,600 to 1,800 rpm; torque, 541 to 3,360 lb-ft; horsepower at 100 rpm, 10.3 to 64; minimum bore, ¾ to 2 3/16 inches.

Silicone Sponge Rubber

Connecticut Hard Rubber Co., New Haven, Conn.

Silicone sponge rubber that is stable within wide temperature limits is being used extensively as a vibration damping material in a variety of applications. It is suitable as an oven seal where temperatures reach 500 F and as a seal in aircraft cockpits where the surrounding air is —70 Fahrenheit. Density is about half that of solid silicone rubber. Usually made in extruded shapes, the material is also available in sheets and as molded items.

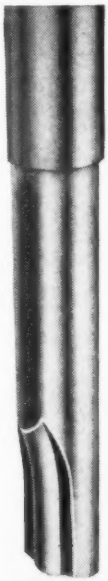


Oil-Tight Pilot Light

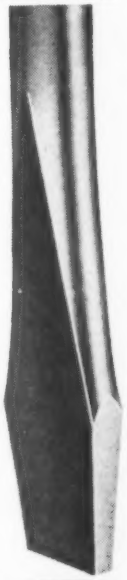
Square D Co., 4041 N. Richards St., Milwaukee 12, Wis.

Pilot light has been designed for machine tool applications where cutting oils and coolants are apt to produce failures. Unit is panel mounted through a hole of 1-7/32 in. diameter. Construction permits mounting on panels as thin as 1/16 in. or as thick as ¼ inch. Color caps of

TYPE "A" ASSEMBLY BIT



COMMON SCREWDRIVER



CLUTCH HEAD *Invites Comparison With* ALL *Other Screws...*

. . . RECESSED HEADS AS WELL AS SLOTTED

It is generally conceded that recessed head screws have outmoded the use of slotted head screws on modern assembly lines. For that reason, CLUTCH HEAD user quotations . . . recording production increases ranging from 15% to 50% . . . are based on comparison with *other types of recessed head screws.*

Only Clutch Head provides Center-Pivot entry for safe automatic straight driving.
Only Clutch Head has non-tapered driving to eliminate the skid hazard of "ride-out."
Only Clutch Head offers this all-square driving contact as a safety factor.
Only Clutch Head eliminates the fatigue of end pressure for easier, faster driving.
Only Clutch Head has the Lock-On which permits one-handed driving from any angle.
Only Clutch Head delivers Bit durability that drives up to 214,000 screws, non-stop.
Only Clutch Head has a recess basically designed for common screwdriver operation.

America's Most Modern Screw invites you to make your own comparison . . . to evaluate these exclusive CLUTCH HEAD features...right

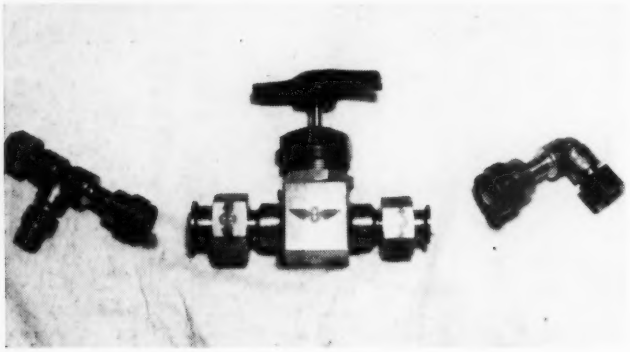
CLUTCH HEAD · SCREWS ·

at your own desk. Your request will bring you, by mail, package assortment of screws, sample Type "A" Bit, and Illustrated Brochure.

UNITED SCREW AND BOLT CORPORATION

CLEVELAND 2 CHICAGO 8 NEW YORK 7

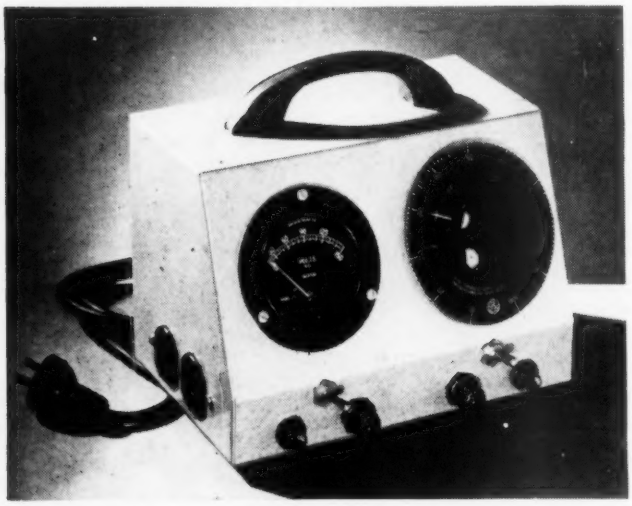
wide angle visibility are available in clear, white, red, amber, green and blue. The a-c version has a built-in transformer permitting the use of a 6 v, incandescent lamp with a miniature, bayonet-type base. Shock and vibration failures are thus minimized. The d-c version incorporates a 110 v candelabra screw-base, neon lamp.



High-Pressure Shut-Off Valve

Greer Hydraulics, Inc., 454 18th St., Brooklyn 15, N. Y.

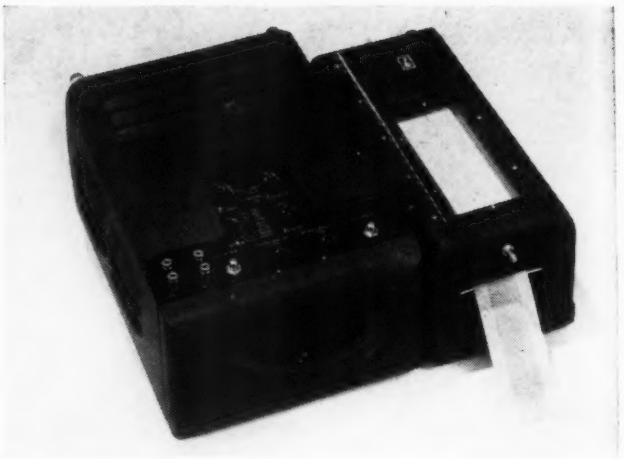
Induction brazed joints make this poppet type shut-off valve suitable for use with line pressures up to 8,000 psi. The flush-mated unions permit simple installation without spreading adjoining pipes and all working parts can be disassembled for poppet and seat replacement without removing body from the line. Light pressure on the handle gives rapid, positive shut-off action. Line sizes of $\frac{3}{4}$ and 1 in. are available and additional sizes are scheduled for future production.



Portable Voltage Controller

Andrew Technical Service, 111 E. Delaware Place, Chicago 11, Ill.

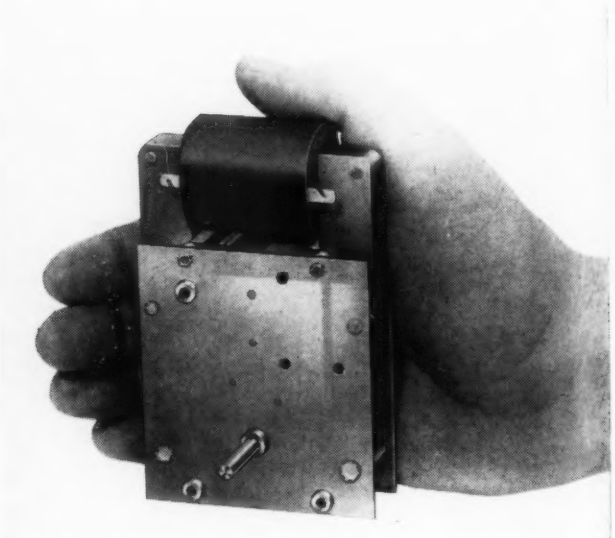
Self-contained and measuring only 9 x 8 x 7 in., this portable laboratory and research instrument provides accurate control of a-c output from 0 to 135 volts. A 405 w variable auto-transformer limits the current capacity to 3 amp. Each of the two plug-in receptacles has a toggle switch, pilot light and cartridge type screw-in fuse easily replaceable from the front of the steel housing. Input rating is 115 v, 50-60 cycles, single phase.



Strain Amplifier

The Brush Development Co., 3405 Perkins Ave., Cleveland 14, Ohio

The BL-310 amplifier, when used with the Brush magnetic direct inking oscillograph, is a complete package unit for the measurement of strains. It can be simply operated, producing records which are immediately available and easily interpreted. Equipment records either static or dynamic strains up to 100 cps, and direction as well as magnitude of the measured strain can be read from the chart. Amplifier contains two legs of the Wheatstone bridge network. The third and fourth legs are connected externally, one being the active gage, the other for sensitivity doubling, or temperature compensation. The analyzer is readily calibrated for individual gages, so that strain can be read directly between 10 and 40,000 micro-inches per inch. Although primarily intended for use with the SR-4 120 ohm strain gage, it is also applicable for use with any resistance-sensitive pickup. Power consumption is 135 watts.



High-Torque Motor

T. C. Smith Mfg. Co., Springfield, Ill.

While drawing only 20 watts, this small fractional horsepower, shaded pole, induction motor develops 75 oz.-in. stalling torque. Over-travel of the output shaft is pre-

EVERY DESIGN ENGINEER

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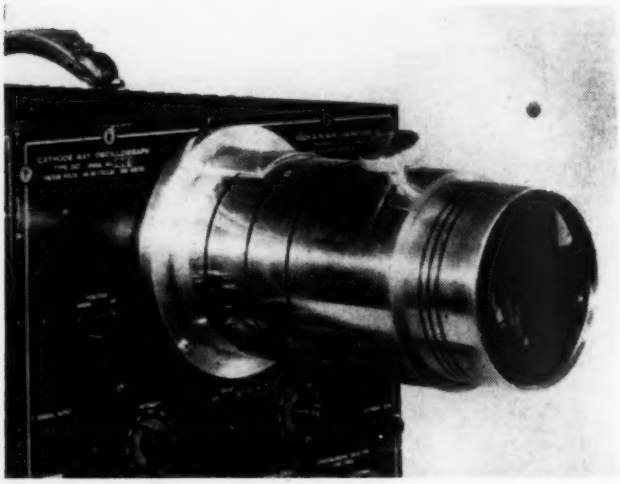
Write for your copy of Contract Forming or mail blueprints with engineering details.

★ ★ ★

THE CYRIL BATH COMPANY

6700 Machinery Avenue, Cleveland 8, Ohio

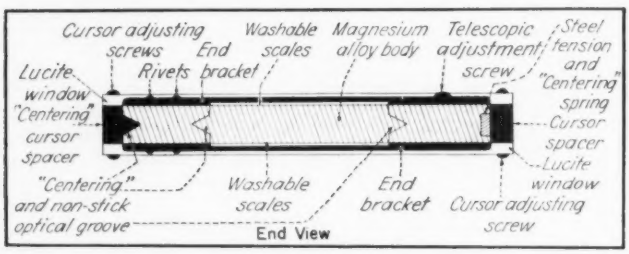
vented by a magnetic clutch activated by de-energizing the motor. Construction is of aluminum and bearings are oil impregnated powdered metal. A built-in gear train of varying ratios is used to change stalling torques and input wattages. Powered from a 115 v 60 cycle source, motor is suited for application to coin machines, directional antennae and many diversified uses.



Oscillograph Projection Lens

Allen B. Dumont Labs., Inc., 2 Main Ave., Passaic, N. J.

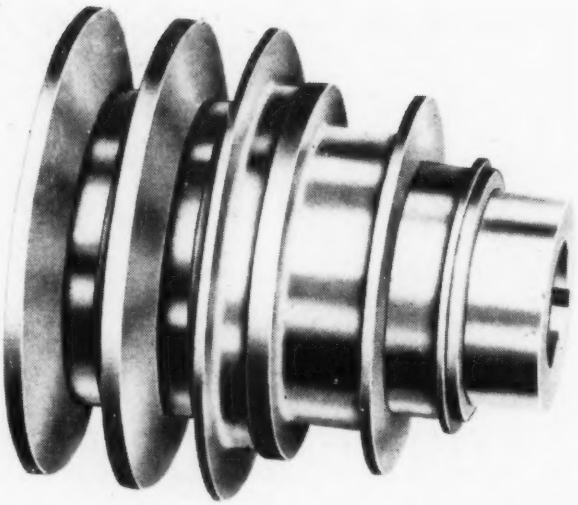
Type 2088 is a two-element, symmetrical objective lens for projecting oscillograms on a large screen. It projects well-defined wave traces appearing on a 3 x 3 in. tube screen to distances beyond 8 ft, resulting in a screen image up to 12 x 12 feet. Relative aperture is f:3.3, focal length is 7.7 in. and axial light transmission is approximately 85 percent. A directive screen is recommended under conditions of high ambient light. Approximate focus is made by sliding the telescope barrel, critical focus by adjustment of the knob working in the diagonal slot. Mounting flange has four holes that line up with threaded holes in the oscillograph panel. Best results are obtained with Types 5RP-A, 247-A and 248-A DuMont oscillographs.



Magnesium Alloy Slide Rule

Pickett & Eckel, Inc., 11 S. Fremont Ave., Alhambra, Calif.

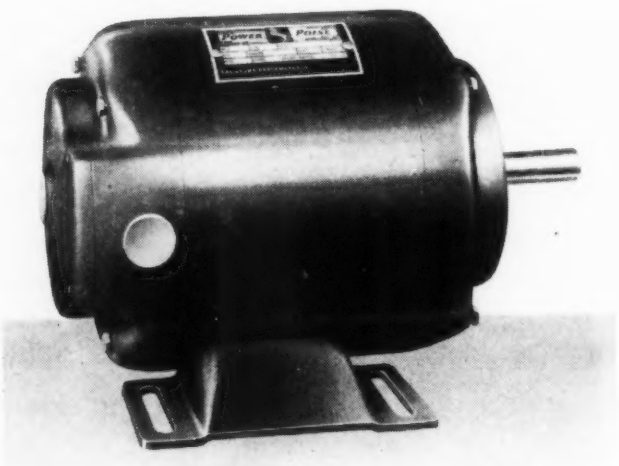
Constructed of plastic-covered magnesium alloy, orthophase log log slide rule is non-warping and unaffected by climatic conditions. Other improvements over the standard wooden rule are precision manufacture to 0.001 in. tolerance, cursor window supported free of scale surface, "centering" non-stick optical groove, easily adjusted screws for lining up scales, and non-fade scales. Unit measures $12\frac{1}{8}$ x $1\frac{1}{2}$ x $\frac{1}{8}$ in.; weighs four ounces.



Twin V-Belt Clutch

V-Belt Clutch Co., 3757 Wilshire Blvd., Los Angeles 5, Calif.

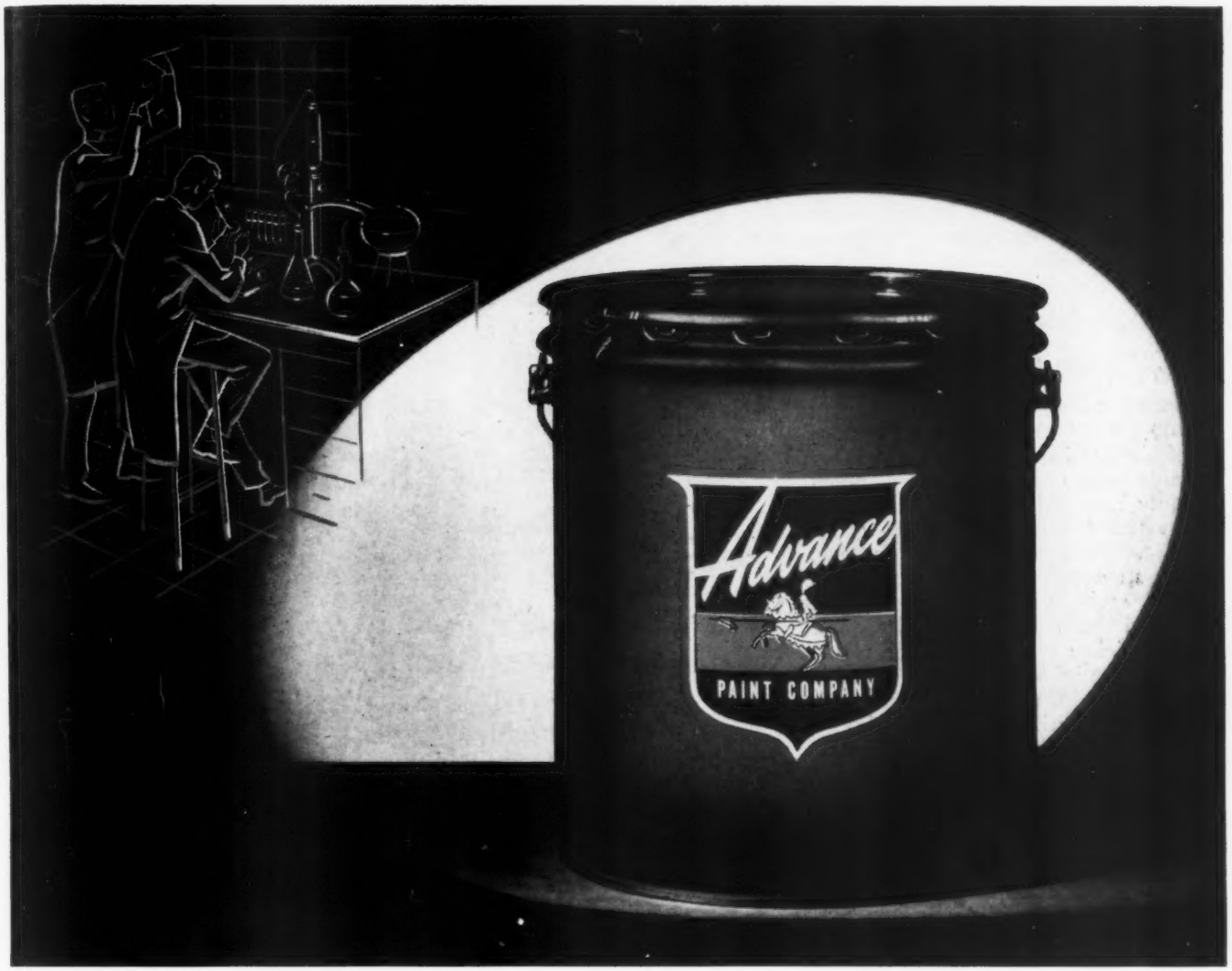
Model 2DC Ball-Lok twin V-belt clutch provides smooth starting under heavy loads with equalized pressure on the belts. When the clutch is set for idling position, the belts ride on free turning bearings of double stepring design; when in driving position the belts are gripped by and ride up on the pulley sidewalls. Shifting force is applied to the walls of the open-channel sleeve. Shifter-fork assemblies with friction shoes or conventional bronze shifting collar units are available. Unit is rated at 5 to 10 hp for application to gasolene engine mountings and industrial drive requirements. Pulley diameter is $3\frac{3}{4}$ in., length $4\frac{1}{8}$ in.; weight, 3 lb 6 oz; shaft size range, 1, $1\frac{1}{8}$, $1\frac{1}{4}$ inches.



Capacitor-Start Induction Motor

Brown-Brockmeyer Co., Dayton, Ohio

Fan-cooled condenser and springless actuating switch are enclosed within the housing of this a-c capacitor-start induction motor. Dynamically balanced rotor rides in "Life-Seal" ball bearings mounted in the steel housing. Suitable for either horizontal or vertical operation, motor is applicable to air-conditioning equipment, ventilating



5 GALLONS OF LACQUER 50 YEARS OF EXPERIENCE

Here's a drum of Advance Lacquer. It contains fifty years of experience . . . and five gallons of a fine finish.

Service technicians of the Advance Paint Company have developed formulations to solve thousands of individual finishing problems. As a result, characteristics have been built into Advance finishes that make them easy to apply and quick to dry, speeding up your finishing operations. All the metal finishes manufactured by the Advance Paint Company are made to satisfy the most exacting requirements . . . are adapted to low-cost finishing operations.

This experience can go to work for you. An Advance field representative will come into your plant to help you solve *your* finishing problems.

Manufacturers of Industrial Finishes

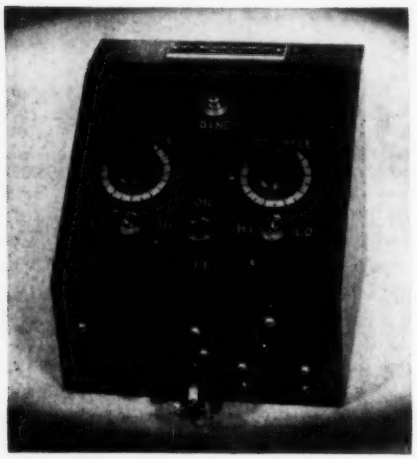
Advance PAINT COMPANY
INDIANAPOLIS, INDIANA

fans and blowers, stokers and oil burners. Models rated at 1725 rpm are available in the ¼ to 1½ hp range for use on 115/230 v, 60 cycle, single phase power supply.

Acrylic Plastic Sheeting

Rohm & Haas Co., Knoxville, Tenn.

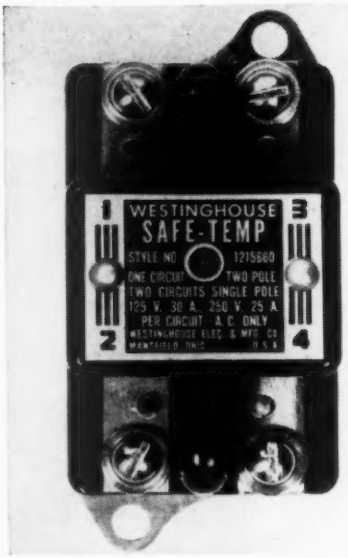
Sheets of acrylic plastic measuring 100 x 120 in. are widening the scope of designs based on plastics. Many large dimension applications previously restricted to other materials or segmented constructions are now possible. Among these are auto tops, aircraft display cases and special uses such as in radar stations where the optical perfection and radar wave transmission properties of the plastic make it suitable. Sheets are available in ¼ to ½ in. thicknesses. With expanded facilities, sheets will also be produced in corrugated form.



Repeat-Cycle Timer

G. C. Wilson & Co., Chatham, N. J.

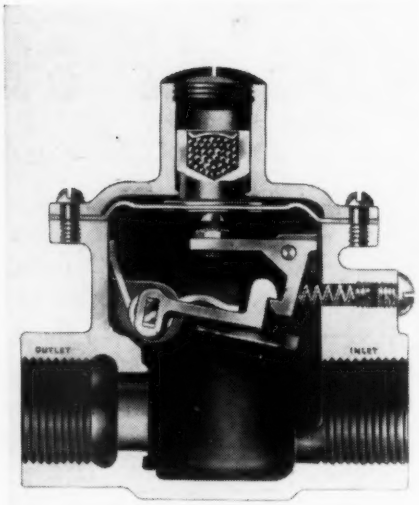
The Model No. 1 repeat-cycle timer provides independently variable control of "on" and "off" time intervals. "On" intervals can be varied from 0.2 to 200 sec, "off" intervals from 0.1 to 60 seconds. The push button at the top synchronizes the timer cycle with external equipment. Cyclic operation is produced by the interaction of two variable electronic resistance-capacitance elements. The "on" and "off" control dials provide interval adjustment, within the high or low ranges. Double pole, double throw relay contacts are rated at 0.10 amp each, 115 v to 2 amp, 460 v a-c non-inductive. The standard 6 x 6 x 6 in. unit operates from 105-120 v, 60 cycle power; d-c units are available.



Water Temperature Control

Westinghouse Electric Corp., 306 4th Ave., Box 1017, Pittsburgh, Pa.

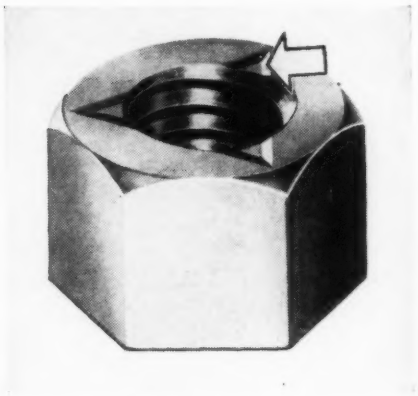
The Safe-Temp automatic thermal protection control for electric water heaters utilizes heat from the tank wall for actuation. Electric power to the heater will be cut off between 180 and 205 F depending upon the type of tank mounting and wattage of the heating element. Upper limit is set at 205 F so that water cannot reach the boiling point even at relatively high altitudes. Unit is fully enclosed in a plastic cover that excludes dust and insulates current-carrying parts.



Automatic Shut-Off Valve

Security Valve Corp., Los Angeles, Calif.

The gravity-actuated shut-off mechanism provides positive action and minimizes wear in the Warden automatic low-pressure shut-off valve. Protection against fire and explosions resulting from gas accumulations and pressure variations is assured with this weight-loaded assembly. Bodies fit ¾ and 1 in. standard-thread lines. Bronze units weigh 6 lb, aluminum alloy units 1½ lb, both having a length of 4½ in., a width of 4½ in., and a height of 6½ inches.



One-Piece Lock Nut

Grip Nut Co., 308-J S. Michigan Ave., Chicago 4, Ill.

The Gripco one-piece lock nut has been redesigned with widened and deepened triangular deflections in the upper face. The greater area depression of threads permits repeated removal and reinstallation without loss of locking efficiency. Utility is increased as the unit can be used on threads not held to close tolerances. The presence of oil, water or chemicals on the threads does not affect locking action.

Constant Volume Pump

Sundstrand Machine Tool Co., Hydraulic Div., Rockford, Ill.

The Rota-Roll pumping member design produces quiet operation of the Model 5W constant volume hydraulic pump. With this design, the smaller

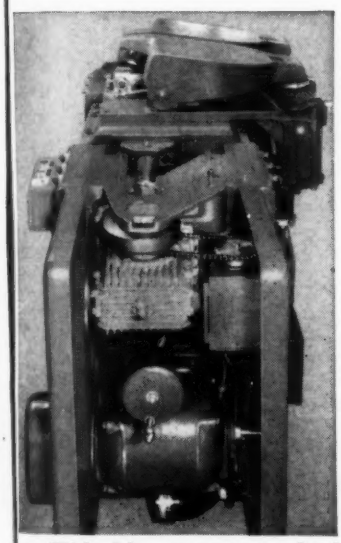
SMALLER GEARS do NOT mean SHORTER LIFE

Not when you are using Cone-Drive gearing for the job. For Cone-Drive gearing with its larger contact per tooth and MORE TEETH IN CONTACT gives you vastly lower inherent unit pressures . . . i.e., greater load capacity with smaller gears.

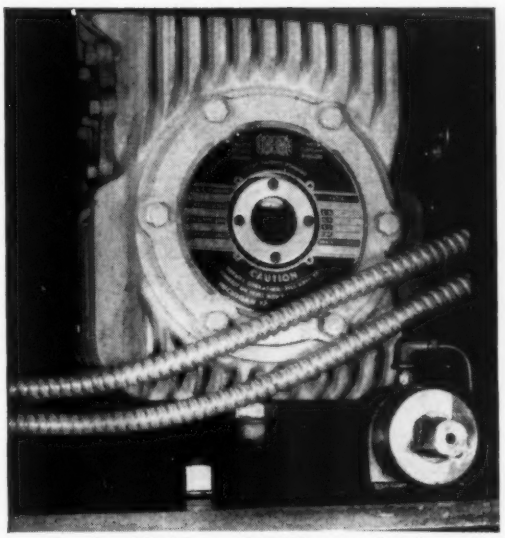
And here's a real design short-cut: Where possible, use a *standard* Cone-Drive speed reducer. You'll be surprised in how small a space it will fit and how much money it will save.

Ask for Bulletin No. 8901a

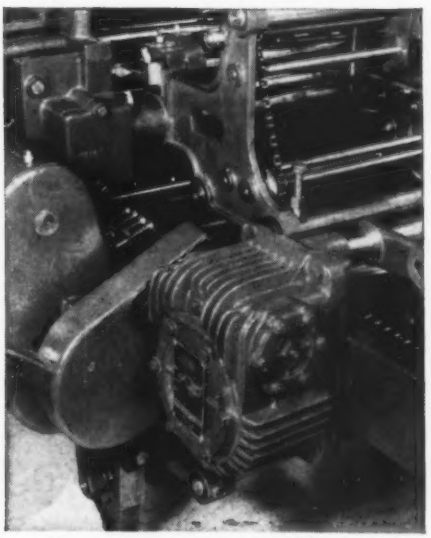
CONE-DRIVE DIVISION
MICHIGAN TOOL COMPANY
7171 E. McNichols Road • Detroit 12, U. S. A.



With this compact *standard* Cone-Drive speed reducer, Progressive Welder, in its flash welders, got "longer life, lower inertia forces, freedom from backlash despite higher loads . . ."

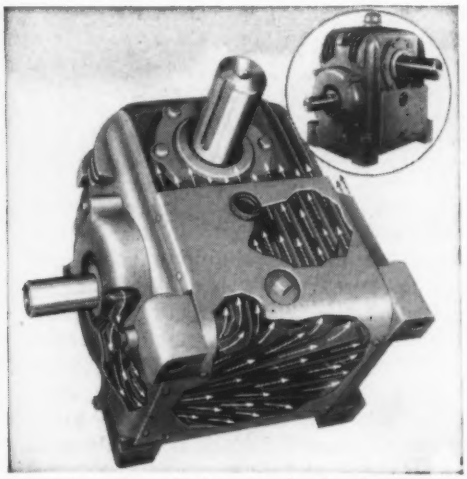


In the Michigan "870" gear finisher, the smoother slide movement drive—key to the 870's new higher standards of accuracy and versatility—is through a *standard* Cone-Drive reducer, compact and light enough to go in the machine head.



Here is a paper box machinery manufacturer who found it a lot less costly to use a *standard* Cone-Drive reducer in place of former gear-change boxes in his machines—and got increased load carrying capacity with longer life.

A compact *standard* Cone-Drive reducer drives the conveyor on several new lime-spreader trucks, such as this one by Weston Dump Body—a tough job when running with full loads over rough fields.



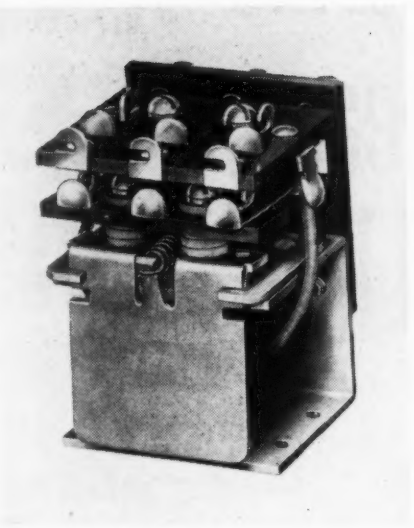
Most Cone-Drive *standard* reducers can also be water or fan-cooled—in which case you can just forget about thermal ratings.

or inner member is keyed to a shaft and drives the outer member at a speed 25 percent lower than the motor speed of 1200 rpm. Differing from the conventional, the pumping members have a special tooth form that provides increased durability. Both roller and rotor are self-emptying and cavitation at the inlet is reduced through special porting. Overall efficiency is 85 percent and the eight different versions of the Model 5W cover the range from 3 to 10 gallons per minute.

Indicating Pressure Switch

Square D Co., Milwaukee, Wis.

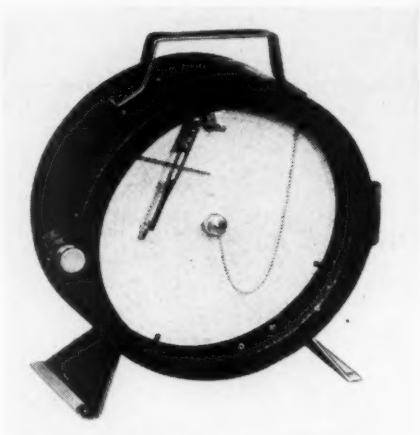
Class 9012 switches are designed to cover the wide range of applications for the control of pneumatic or hydraulic machines such as welding equipment, machine tools and high pressure lubricating systems. Positive quick-make and quick-break action is assured by use of a single-pole, double-throw snap switch mechanism. Separated, non-overlapping normally open and normally closed circuits with double-break silver contacts are provided. Switch mechanism is enclosed in a molded case of non-carbonizing melamine. Switch enclosures are of die-cast aluminum, drip-tight and oil-resistant. An indicator flag behind the window facilitates proper setting of the trip point and shows any pressure surge or other objectionable condition. Adjustment is made by the convenient adjusting knob. Bellows-actuated types are available in a variety of ranges up to 1,000 psi. Piston-actuated controls handle 3,000 psi pressures.



Control Relays

Allied Control Co., Inc., 2 East End Ave., New York 21, N. Y.

Intended for all-purpose usage in electronic, aircraft and other industries, Type PO and POY control relays are compact and can be supplied hermetically sealed. Non-inductive silver contacts, 2-, 3-, and 4-pole normally closed, normally open or double throw, carry 15 amp at 24 v d-c or 110 v a-c. Type PO coils are rated up to 220 v, 25 and 60 cycles at 10.5 va; 120 v d-c at 2.5 watts. The Type POY semi-sensitive, dual-coil relay is applicable for d-c operation direct from the plate of a vacuum tube or limited power circuit. Coils are rated up to 110 v d-c at 1 watt. Dimensions of the large 4-pole relay are $2\frac{1}{4}$ x $1\frac{7}{8}$ x 2 3/16 inches.



Recording Thermometer

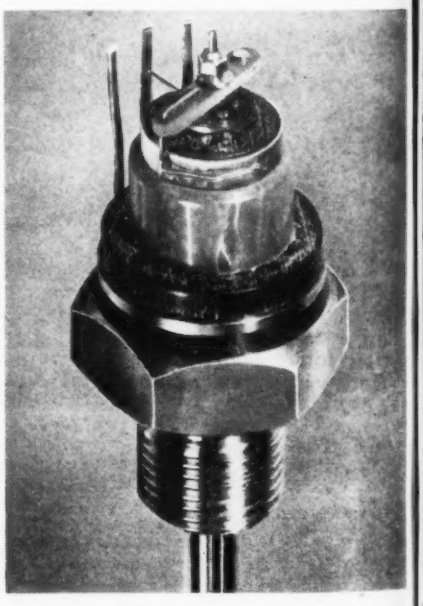
Weksler Thermometer Corp., 52 W. Houston St., New York 12, N. Y.

Liquid or air temperatures in all standard ranges can be measured with this single or double pen 8 in. chart size recording thermometer. The durable, accurate movement is stainless steel with micrometer adjustment. Bulbs are of varying size with five feet of braided armor tubing attached with plain, union or separable socket connections. Unit can be supplied for wall or flush mounting and for portable use. Standard 24 hour or special period chart drives, either hand wound or motor driven, can be supplied.

Metal Filter Cloth

Michigan Wire Cloth Co., 2100 Howard St., Detroit 16, Mich.

Specification 4200 metal filter cloth is equal to 200 mesh in filtering and straining action, yet is seven times as strong. Weave is Plain Dutch having a warp count of 40 mesh. The Monel metal and brass wire woven to these specifications has a definite stiffness that keeps the cloth flat and free from curling. Weight of 100 sq ft of Monel cloth is 42 lb; flow rate per square inch is 7.3 gallons per minute.



Temperature Transducer

G. M. Giannini & Co. Inc., 285 W. Colorado St., Pasadena 1, Calif.

The Type 4911 temperature transducer for telemetering applications where space is at a premium is one inch in diameter. A temperature-sensitive bi-metallic element, encased in a small tube, rotates a standard microtorque potentiometer. Any change of position of the element due to temperature variations, results in large voltage outputs from the potentiome-

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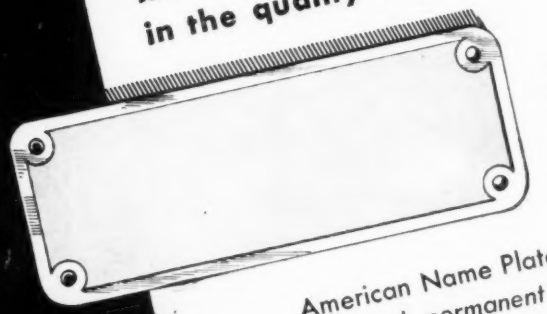

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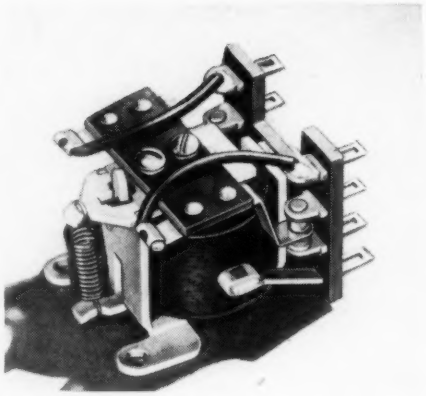
ter. Voltage outputs are of a magnitude suitable for recording with oscillographs, galvanometer-recorders, and telemetering systems. Standard resistance for the instrument is 5,000 ohms, but resistances are available from 100 to 20,000 ohms. Designed for a temperature range from —65 C to +150 C, transducer has a linearity of 1 percent, an accuracy of 1 percent, and a sensitivity of 1 C or less. Standard response time is 2 sec for a 5 degree change in temperature. The size, weight, and voltage output make this an ideal instrument for the transmission of compartment temperatures, fuel temperatures and ambient air temperatures.

Microammeter

Radio Corporation of America, RCA Victor Div., Camden, N. J.

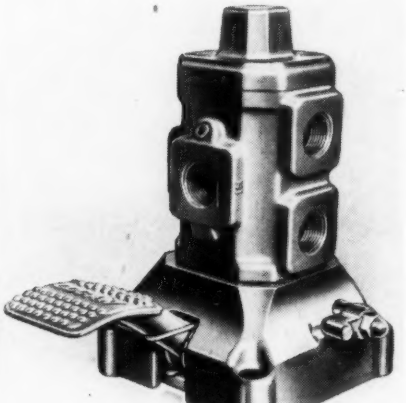
Type WY-84A ultra-sensitive electronic microammeter accurately measures d-c currents down to one-billionth of an ampere. The portable, battery-operated, vacuum-tube instrument can be used with multiplier photo tubes in measuring light intensities and gas densities, and in atomic research as a sensitive current-measuring device for checking ionization chamber currents in radioactive material control. For industrial use, the instrument will facilitate corrosion and electrolysis studies, and can be used with precision gaging equipment. Six range settings permit a choice of the most convenient range. The current sensitivity is greater than that of existing portable meters of the pivot or suspension type and approaches that of the average reflecting galvanometer. By adding external multipliers, the microammeter can be converted to a high-resistance voltmeter.



Midget Relay

Struthers-Dunn, Inc., 150 N. 13th St., Philadelphia 7, Pa.

Type 119XBX midget relay is adaptable to electric vending machines and similar equipment. Measuring $1\frac{3}{16}$ in. high, $1\frac{7}{8}$ in. deep and $1\frac{3}{8}$ in. wide, relay is easily mounted and connections readily accessible. Double pole, double throw contacts are rated at 5 amp and coils are available for any voltage up to 115 v, 60 cycles. All 115 v units are adjusted to operate at 85 v or above.



Hydraulic Control Valve

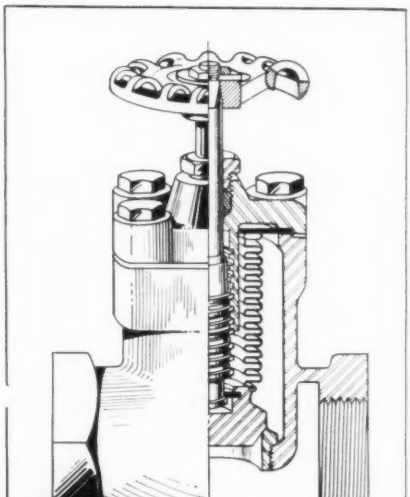
Logansport Machine Co., Inc., Logansport, Ind.

Latching or free control of double acting hydraulic cylinders is provided in the Model 7025 foot-operated 4-way valve. Piston is pressure balanced and no valve seats or packings are used other than stem seals at each end. Switching from indefinite dwell to instant release is made by turning lever in the base. Upper body can be rotated 360 deg on the base to four positions at 90 deg intervals. Model 7025 is available in standard port sizes from $\frac{1}{4}$ to 1 inch.

Flow Sights

Oil-Rite Corp., 3482 S. 13th St., Milwaukee 7, Wis.

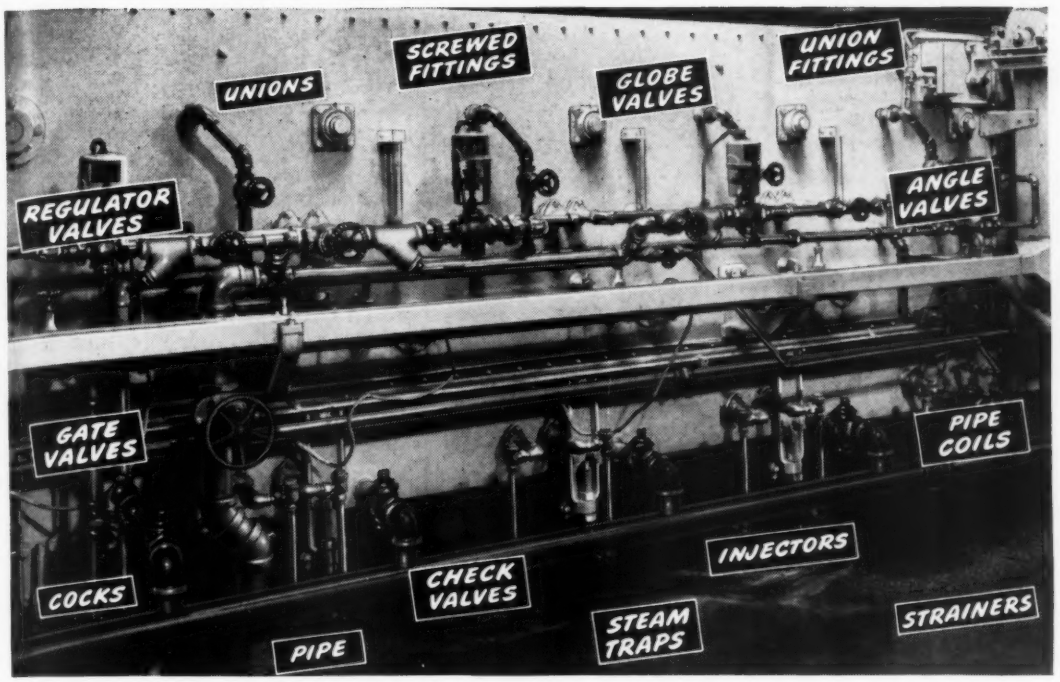
Style SFX flow sights provide maximum visibility of gravity or pressure fed liquids. Flow is downward through a nozzle on the inlet side. Nozzle can be provided with an orifice of diameter ranging from $\frac{1}{8}$ to 9/16 inch. Additional flow control can be obtained by using a standard globe, angle or gate valve. Aluminum alloy end-plates carry the lucite or glass (for temperatures above 150 F) sight cylinder between cork gaskets. Assemblies are available in three body sizes having sight diameters of $1\frac{1}{2}$, 2 and $2\frac{1}{2}$ in. with either $\frac{1}{8}$, $\frac{1}{4}$, $\frac{3}{8}$, $\frac{1}{2}$, $\frac{3}{4}$ or 1 in. female pipe threads.



Packless Valve

Robertshaw-Fulton Controls Co., Fulton Sylphon Div. Knoxville, Tenn.

Seamless metal bellows provide a leak-proof seal between the valve disk and body of the Series 3000 valve. Utility is thus greater than with conventional designs under both pressure and vacuum conditions. Bellows are made of stainless steel, Monel, phosphor bronze, brass and other materials. Valve bodies are stainless steel, bronze, cast iron, cast steel and Monel metal. For high-vacuum and specialized services, composition disks can be substituted for the standard metal part. Valves are available in sizes from $\frac{1}{4}$ to 3 in. with screwed, welded or flanged ends. Temperatures up to 700 F can be withstood.



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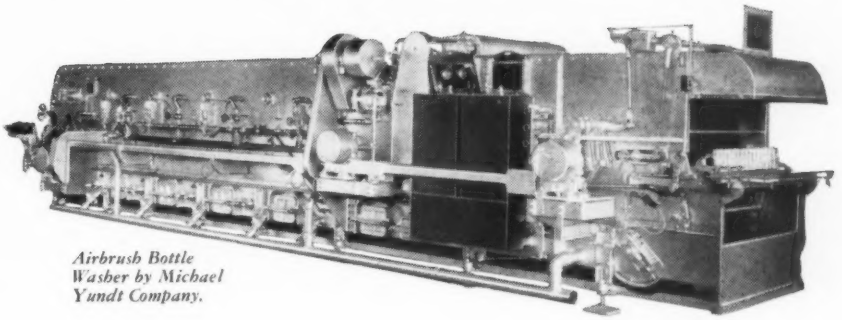

Airbrush Bottle Washer by Michael Yundt Company.

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NEW BOOKS

Precision Investment Castings

EDWIN LAIRD CADY. *356 pages, 6¼ x 9¼ in. Published by Reinhold Publishing Corp., 330 W. 42nd St., New York 18, N. Y.* $6.

This book has been organized to be of use to both production and design engineers. The first few chapters tell the engineer what precision investment casting is, what it does, and how it does it. From these chapters, the designer can make up his mind whether this process will serve his purpose; and if it will, whether he should set up the process in his own plant, or have the work done in an outside shop.

The remaining chapters tell how to design parts to get best results from precision casting. Advantages and limitations of the process are described, and predictable lines of future development are indicated.

Electric Resistance Welding

Published and edited by HAROLD S. CARD, 840 *Euclid Ave., Cleveland* 14, *Ohio. 22 pages* 8½ x 11. $1.

A bibliography of published resistance welding literature from January, 1936 to June, 1947. The pamphlet contains titles, authors and publication dates of 646 articles on resistance welding subjects that have been published in 49 technical and industrial magazines during the period indicated in the title. Most of the titles are accompanied by topical synopses indicating the scope and subject matter of the respective articles. Each title is given a key number by which the entire list is indexed under 133 subject headings. Lists of current standards publications and books and booklets are included. This bibliography will be an asset to libraries, authors and both manufacturing and engineering personnel who deal with resistance welding.

Improving Supervision

FRANK CUSHMAN *and* ROBERT W. CUSHMAN. *232 pages. 4⅞ x 7¼ in. Published by John Wiley and Sons Inc., New York, N. Y.* $2.50.

An extremely frank and revealing discussion of human relation problems encountered by supervisors in industrial and business organizations. Of particular interest, is the discussion of the sequence of events that occur in supervisory responsibilities when small companies grow into large industrial organizations. Line and staff types of

supervisory positions are described. Supervisory job analysis, development, training and job planning are discussed. Such related supervisory factors as waste control, cooperation, verbal and written orders and carelessness are treated in separate chapters. Worker job training, job interest satisfaction, discipline, loafing, absenteeism and working conditions are evaluated from the supervisor's point of view. Subjects of current interest are discussed in the last two chapters. These are: grievances, and rating employees. Including an index, this book will serve as a valuable reference and guide for all personnel working in or toward supervisory positions.

Plastics Dictionary

THOMAS A. DICKINSON. *312 pages, 6¼ x 9¼ in. Published by Pitman Publishing Corp., 2 W. 45 St., New York, N. Y.* $5.

This book consists of a mixture of technical terms and tradenames used in the plastics industry. Some of the tradenames are unfamiliar even to one who is in the plastics industry—this stems from an abundance of West Coast and British products. In general, however, the book is valuable to an engineer who wishes to become familiar with the jargon of the plastics industry.

Tool Steel Simplified

FRANK R. PALMER, *Vice President, and* GEORGE V. LUERSSEN, *Chief Metallurgist, The Carpenter Steel Company. 564 pages, 6 x 9 in. Published by The Carpenter Steel Co., Reading, Pa. Revised Edition.* $2.

Revised to include new methods, terms and principles for the selection and heat treatment of tool steels, this book contains a wealth of information that tool and die designers and makers ordinarily obtain piecemeal from steel company experts or literature.

The five parts, illustrated with 355 cuts, charts and diagrams, show in simplified form how to specify and heat-treat tool steels; beginning with the definition of terms and winding up with valuable data on testing and trouble shooting.

Part I covers the fundamental concepts of the subject. Chapter 1 discusses the "language" while Chapters 2 to 5 provide a general "getting acquainted" course.

Part II describes a simplified method for selecting the right tool steel for making all sorts of tools. Chapter 6 describes the method, Chapter 7 gives the analyses of twelve steels that will do the job, Chapter 8 discusses a number of examples to show how the

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method works out in actual practice, and Chapter 9 concludes with a very practical means of implementing the method in the form of a simple tool steel selector.

Part III deals with simplified methods for heat treatment. Chapter 10 is devoted to general considerations of methods and equipment; Chapter 11 discusses hardness and toughness; Chapter 12 gives specific information on the group of twelve steels; and Chapter 13 completes the section with a comprehensive discussion of the specialized subject of high speed and hot work steels.

Although the first three parts of the book tell "how to do it," the reader will find his understanding of the subject more complete after reading the chapters in Part IV. Chapter 14 puts an interesting angle on tool design. Chapters 15 and 16 give rules for hot acid etching and timbre and hardenability testing. Chapter 17 tells how to identify steels by their emery sparks. Chapters 18, 19 and 20 discuss three of the most interesting and important phases of heat treating—furnace atmosphere, heating time and quenching. Finally, Chapter 21 contains some practical tips on "trouble shooting."

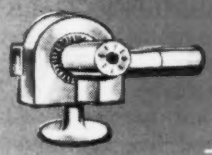
Part V concludes with a few tables helpful to the user of tool steel.

Forming of Austenitic Chromium-Nickel Stainless Steels

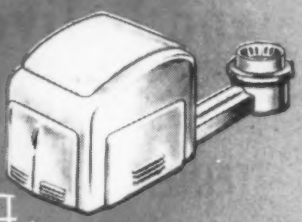
VSEVOLOD N. KRIVOBOK *of the International Nickel Company, Inc.; and* GEORGE SACHS *of Case Institute of Technology. 309 pages, 8¼ x 11 in. Published by The International Nickel Co., Inc.; 67 Wall St., New York 5, N. Y. $4.*

This excellent book, full of detailed information contributed by the principal fabricators of stainless steel, was written to fulfill the evident need for knowledge about the technique of forming austenitic chromium-nickel stainless steels. The need for such data was made clear during the war when the stainless steels were used extensively. The need is still obvious in the ever broadening application of these steels to peacetime activities.

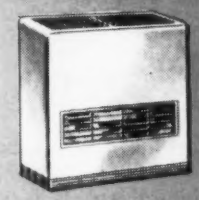
The chapter headings indicate the scope of field covered, these include: Mechanical properties of chromium-nickel stainless steels; forming characteristics of austenitic stainless steels; processing after forming; design, layout and preparation of blanks; equipment, tools and lubricants, bending and straight flanging; forming of curved sections and tubing; forming of contoured-flanged parts; deep drawing of cup-shaped, box-shaped and related parts; double action die forming



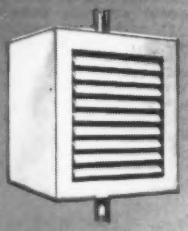
OIL BURNERS



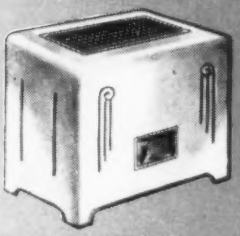
STOKERS



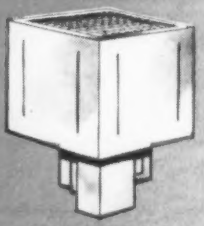
ROOM COOLERS



UNIT HEATERS



SPACE HEATERS



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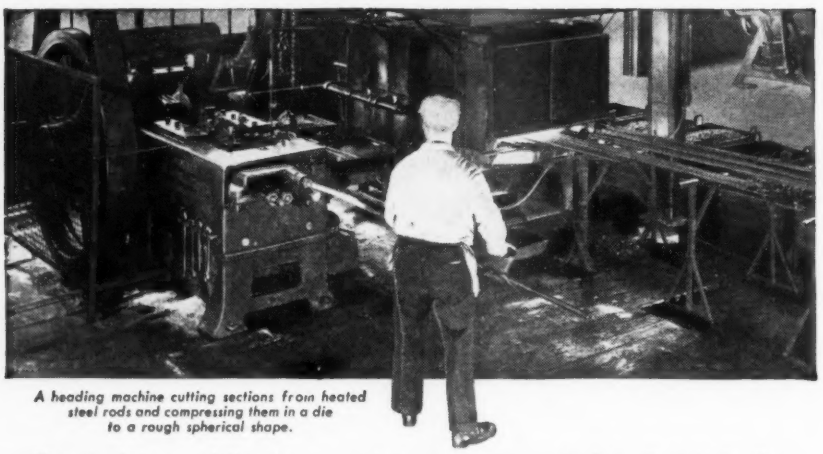

A heading machine cutting sections from heated steel rods and compressing them in a die to a rough spherical shape.

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Many valuable tables of engineering data are presented. More than two hundred line drawings are used to supplement and illustrate the text.

Engineers who are engaged in the design of formed parts will find this book to be a constant source of reference.

Elementary Mechanical Vibrations

AUSTIN H. CHURCH. *First Edition. 200 pages, 6 x 9 in. Published by Pitman Publishing Corp., 2 West 45th Street, New York 19, N. Y. $3.25.*

A concise well ordered text on the fundamentals of mechanical vibrations. The author recognizes the difficulty most engineers have in handling vibration problems. Realizing this, he has wisely organized his material in such a way that it can be used by engineering students and by practicing engineers without injuring the professional pride of the latter.

As a text on fundamentals, the intent is to impress on the reader the physical nature of mechanical vibration in systems rather than to stress the mathematical solution of vibration problems.

Only systems with a single degree of freedom are discussed. A feature of the book is the use of practical examples tying in with each type of vibration system.

Chemical Process Principles Part II, Thermodynamics

OLAF A. HOUGEN *and* KENNETH M. WATSON, *Professors of Chemical Engineering, University of Wisconsin. 416 pages, 5½ x 8½ in. Published by John Wiley & Sons, Inc., 440 Fourth Ave., New York 16, N. Y. $5.*

Fundamental principles of thermodynamics are presented with particular attention to generalized methods. The applications of these principles to problems in the compression and expansion of fluids, power generation, and refrigeration are discussed. It is not attempted, however, to treat the mechanical or equipment problems of such operations.

Considerable attention is devoted to the thermodynamics of solutions with particular emphasis on generalized methods for dealing with deviations from ideal behavior. These principles are applied to the calculation of equilibrium compositions in both physical and chemical processes. A chapter is devoted to the new methods of esti-

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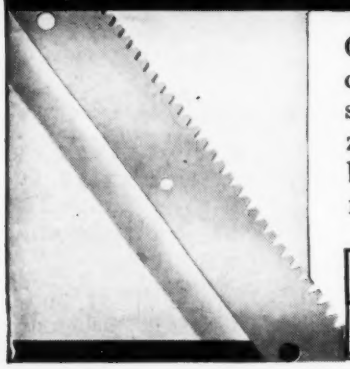

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mating thermodynamic properties by statistical calculations.

The volume contains chapters dealing with thermodynamic principles, thermodynamic properties of fluids, expansion and compression of fluids, thermodynamics of solutions, physical equilibrium, chemical equilibrium, and thermodynamic properties from molecular structure.

Fluid Mechanics of Turbomachinery

GEORGE F. WISLECENUS. *First edition.* 613 *pages,* 6 x 8 *in. Published by McGraw-Hill Book Co., Inc.,* 330 *W.* 42*nd St., New York* 18, *N. Y.* $7.50.

Mr. Wislecenus has had fifteen years of intensive experience in the design of turbomachinery and is well qualified to discuss this subject. Both the author and his book are entitled to respect. The book is a detailed treatment of various types of turbomachinery including axial flow, mixed flow, and centrifugal pumps and compressors, turbines, torque converters and propellers. The author has been rigorous in his treatment of the subject. At the same time he is cautious and repeatedly points out that even refined solutions for fluid-mechanic problems have restricted use in the design of turbomachinery. He emphasizes that for good turbomachinery design the experienced engineer must be prepared to utilize the theoretical approach coupled with a comprehensive test program.

The theoretical behavior of each class of turbomachinery is discussed. The illustrations are well prepared and the adequacy or inadequacy of the theoretical solutions discussed.

Powder Metallurgy

ALEXANDER SQUIRE. $5\frac{1}{4}$ x $7\frac{3}{4}$ *in. Published by Mapleton House,* 5415 *Seventeenth Ave., Brooklyn* 4, *N. Y.* $8.

This is a report of research done at the Watertown Arsenal Laboratory, and issued by the Office of Technical Services. The author, metallurgist at the Watertown Arsenal Laboratory, presents his work on properties of iron powders, physical, chemical and processing, in a series of reports bearing the following titles:

Comparative Properties of 0.55 Carbon Steel Bars Formed by Conventional and Powder Metallurgy Methods.

Critical Survey of Powder Metallurgy and Its Application in Ordnance Design.

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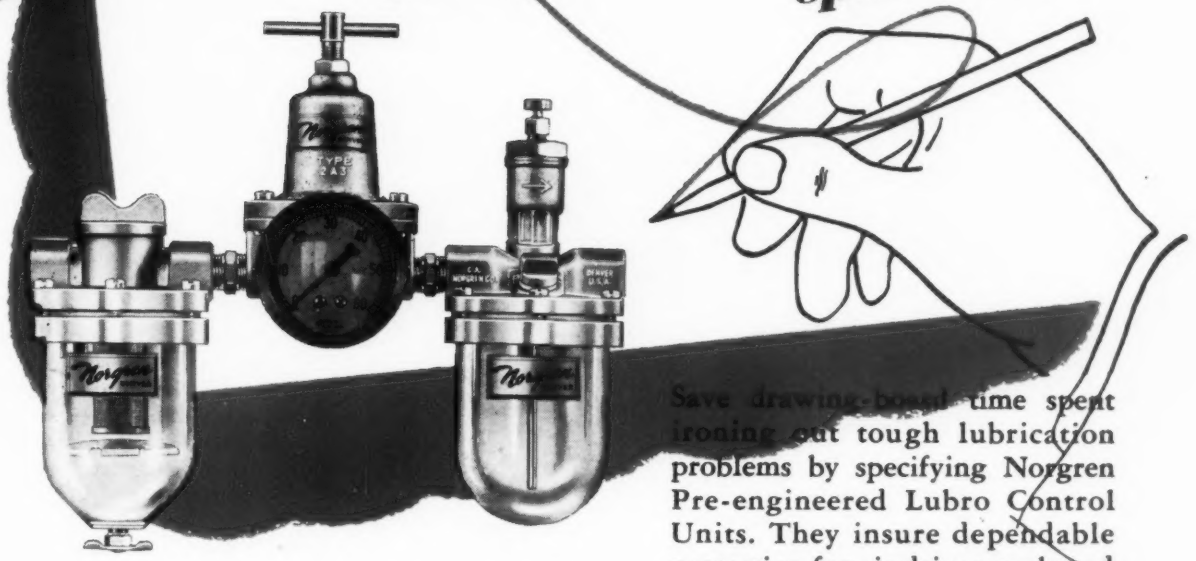

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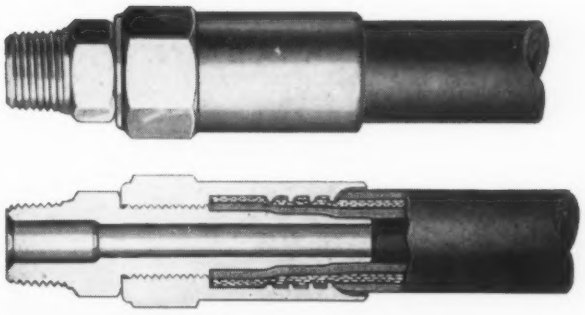

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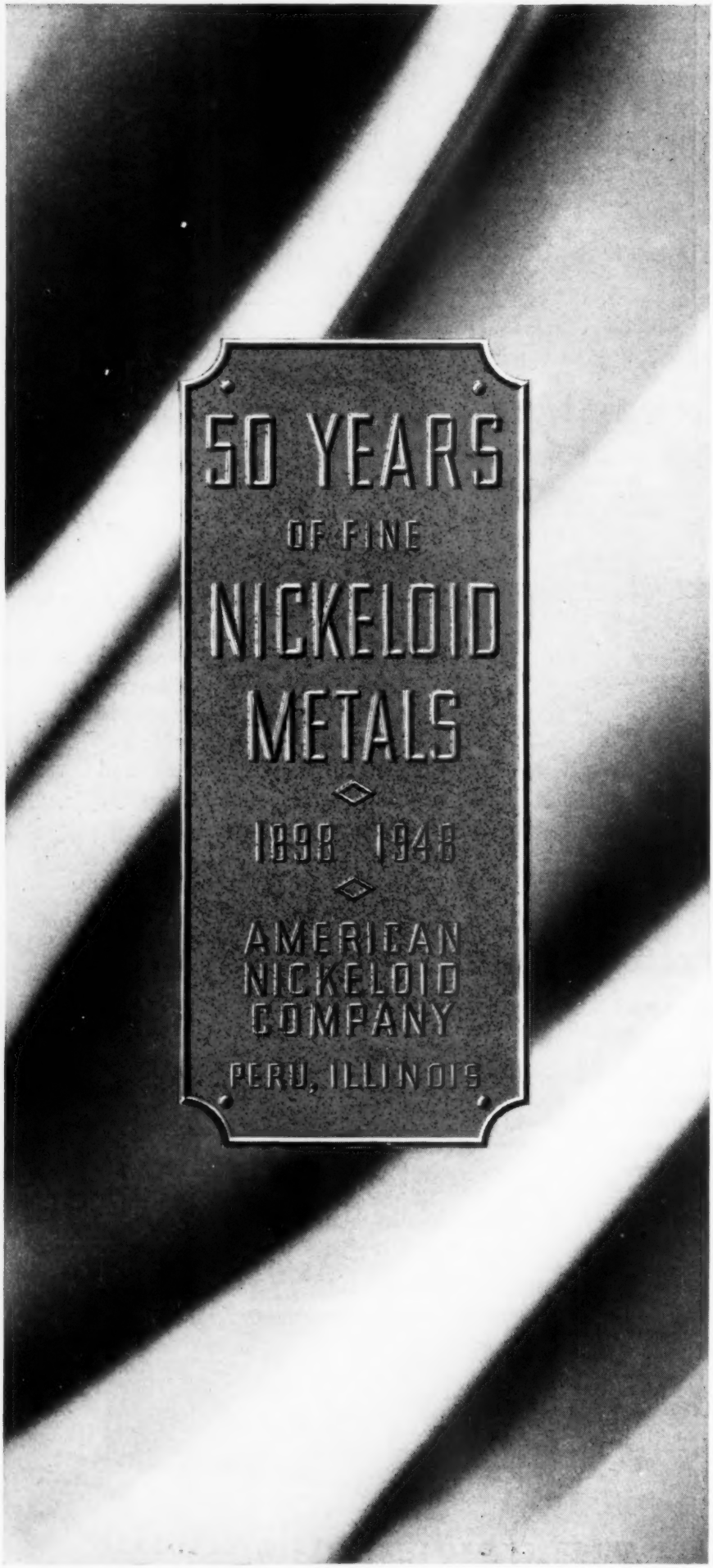

the Density and Mechanical Properties of Iron Powder Compacts.

Density as a Criterion of the Mechanical Properties of Iron Powder Compacts.

Influence of "A" Treatment on the Characteristics of Finely Divided Iron Powder.

The Influence of Processing Conditions upon the Density-Mechanical Property Relationships of Iron Powder Compacts.

Vacuum Tubes

KARL R. SPANGENBERG, *Professor of Electrical Engineering, Stanford University. First edition, 860 pages, 6¼ x 9¼ in. Published by McGraw-Hill Book Co., Inc., 330 W. 42nd St., New York 18, N. Y. $7.50.*

A text for electrical engineers and advanced students, this book gives a comprehensive survey of all physical laws that contribute to the understanding of vacuum tube behavior. Outstanding tube types are dealt with individually and their operating characteristics explained in terms of their internal fields and their influence upon the electron flow. A broad range of tube types is covered, including: Magnetrons, klystrons and ultra high-frequency tubes.

The author develops the fundamental techniques of analysis required for understanding tube behavior, such as determination of the shape of potential fields, solution of electron path equations, and determination of space charge relations.

Recent advances in the field are thoroughly covered, and the material includes a number of items not previously available in book form. Problem sets are included for each chapter, and the book is illustrated with charts, nomograms, and field configurations.

Metals and Plastics

THOMAS P. HUGHES. *First Edition. 373 pages, 6 x 9 in. Published by Irwin-Farnham Publishing Company, Chicago, Ill.*

Metals and Plastics has been written primarily for student engineers, but can be a useful reference for design engineers who wish to brush up on fundamentals. Although the title mentions plastics, only one chapter is devoted to this class of engineering materials. The rest of the book covers methods of production, mechanical and physical properties, and factors affecting the properties of ferrous and nonferrous metals.

All illustrations and charts are clear and the photomicrographs of various metals, in the section on metallurgy, add emphasis to the discussion.

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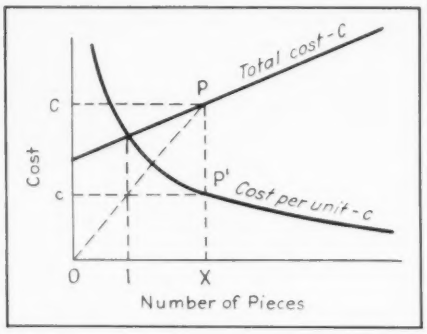
OUR READERS SAY

Cost Curves

To the Editor:

John Van Hamersveld's article "Designing with Dollars", PRODUCT ENGINEERING March 1948, presents extremely useful information. However, the cost diagrams, such as Figs. 2 and 4, are difficult to design as many points have to be calculated. In such instances I found it convenient to work from the total costs which are usually given by the relation $C = b + a\,x$, where b = fixed cost, a = variable cost and x = number of pieces. This is represented in the accompanying diagram



showing x as abscissa and C as ordinate. The cost per piece becomes

$$c = \frac{C}{x} = a + \frac{b}{x}$$

and is represented in the diagram as a kind of hyperbolic curve. This curve does not need to be calculated but can be constructed by a few simple lines as shown. Connect P on total cost curve with zero and project intersection with unity to ordinate P', point on the cost-per-unit curve.

—P. GRODZINSKI, *A.M.I., M.E. London, N. W. 3, England.*

Ed.—Mr. Van Hamersveld comments:

"The suggested graphical procedure will work out nicely if a fixed cost and one variable is used, but due to the complexities of our cost curves, this procedure will not satisfactorily portray a true cost trend for quantity production.

"Our unit cost curves are dependent upon the following variables (as listed in Fig. 4 of the article) for each basic element breakdown.

(1) Set-up Cost—variable with job lot quantities established for factory

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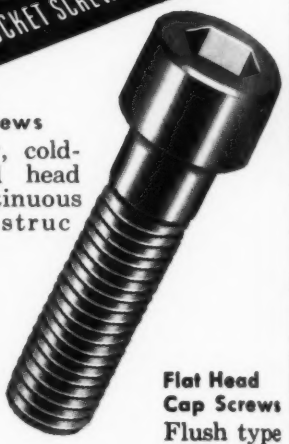
Socket Cap Screws
Sturdy, cold-formed head—continuous fibre structure.



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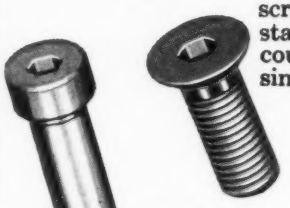

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Socket Set Screws
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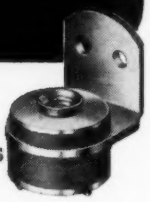

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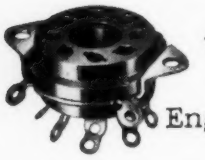

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(2) Labor Cost—variable with quantity using 80% learning cycle dollar cost factors.

(3) Material Cost—purchased on 95 percent learning cycle curve.

(4) Tooling Cost—variable with type, maintenance, recurring tooling, and monthly production rate requirements.

"The sum of these elements comprises the total unit cost of the part for each quantity plotted on the graphical curves as shown in Fig. 2 and Fig. 4 of the article.

"A thorough study of all cost elements for each basic production quantity desired is essential to obtain accuracy of unit costs. In comparison with other designs, this accuracy is necessary to determine the point of equivalency for a cost decision as to which design will be selected for economical production."

Military Research

To the Editor:

We have read with considerable interest your article in the January issue of PRODUCT ENGINEERING titled "Peacetime Benefits From Military Research." The kodachrome view on the cover showing one of the many shops at Wright-Patterson Air Force Base is particularly pleasing.

If possible, we would appreciate having 1,000 reprints of this article for distribution to Air Force Commanders, Public Information Officers, Air ROTC Officers and Air Educators.

—PAUL GAYNOR, *Major, USAF Chief, Services Branch Air Information Division, Department of the Air Force.*

Ed.—We are forwarding the last 400 reprints.

Industry Can Help

To the Editor:

I can only wish you had dug deeper in your January editorial "We Cannot Afford Scientific Bankruptcy." What we need in America is an appreciation of the opposition to such a need. Those who ham-string the affair do not actively "oppose" scientific progress. Actually, they operate by means of immature and emotionally satisfying prejudices, which they—and the community—consider to be rockbottom fundamentals of a most objective and self-evident nature.

The sincerity of the opposition is so complete, and its inability for self-evaluation is so far-reaching that whoever takes on the assignment must

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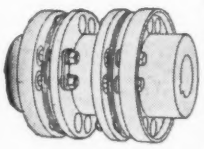

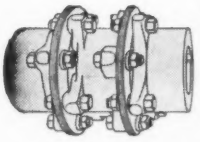

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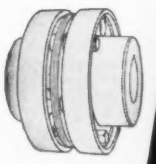

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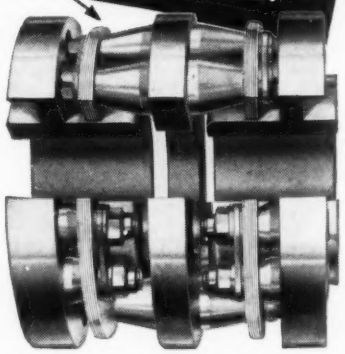

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first see the breadth of sophistication needed to get any constructive action started.

I sincerely commend you for calling on industry to look at a situation that neither educational institutions nor government agencies have done much to improve. —J. A. DOUGLAS
Anniston, Ala.

Ed.: We invite industry's participation in a very lively discussion of this timely subject.

You Can't Have Your Pi and Eat It Too

To the Editor:

As it stands, the equation

$$W_T = \frac{15 \times 33{,}000 \times 12 \times 2}{20{,}000 \times 2 \times 1.400}$$

for calculating the tangential driving pressure of the pinion gear on page 161 of the February issue of PRODUCT ENGINEERING does not give the answer of 67.5 lb as printed. This answer would be correct if the 3.1416 value of π had been carried in the denominator. Shouldn't this have been done anyhow?

—HARPER A. GOOD
Waynesboro, Pa.

Ed.: The editor is lucky—he knew the right answer without solving the equation! The factor for π definitely belongs in the denominator. The editor is also of the opinion that the word "opinion" just below the above equation should naturally be "pinion."

Textbook Supplement

To the Editor:

I am one of fifteen students taking a course in machine tool design at Pennsylvania State College. One of our current assignments is to design a shaper. The article "Gear Trains for Multiple Speeds" by Louis Dodge published in your February issue was of utmost aid in solving our gear train problem.

We would like copies of the article for future reference and would appreciate reprints or tear sheets for the whole class. —C. W. HUFFNAGLE
State College, Pa.

Ed.: All available sets of tear sheets are in the mail.

Orifice Equations

To the Editor:

Joseph Brown's article "Hydraulic Shock Absorber Orifice Designs and Equations" in the February issue of PRODUCT ENGINEERING is indeed timely as it ties in very closely with an investigation we are now conducting. However, the usefulness of the for-

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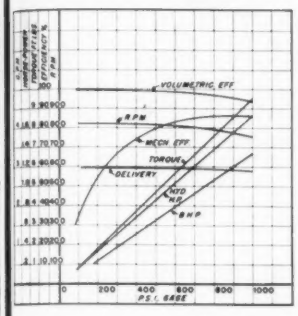
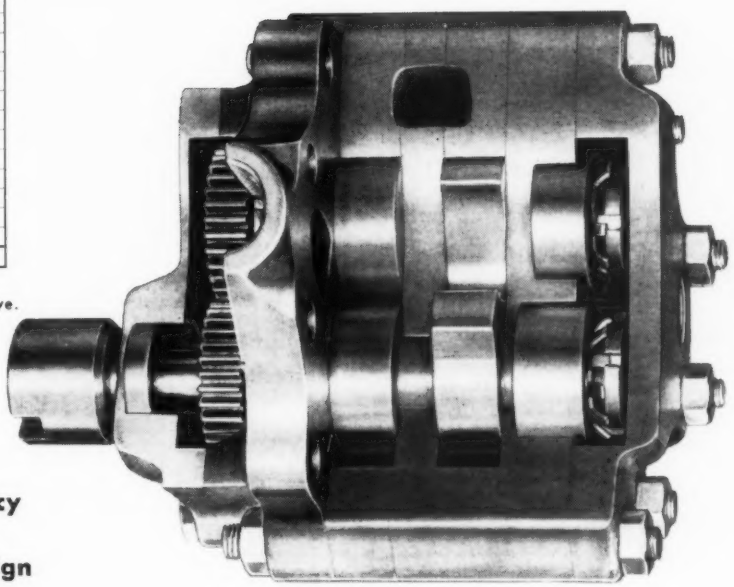


Typical low pressure performance curve.



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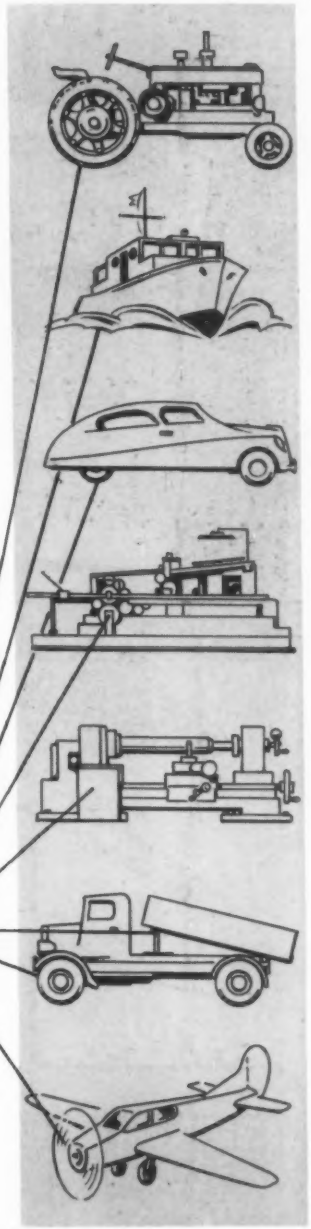
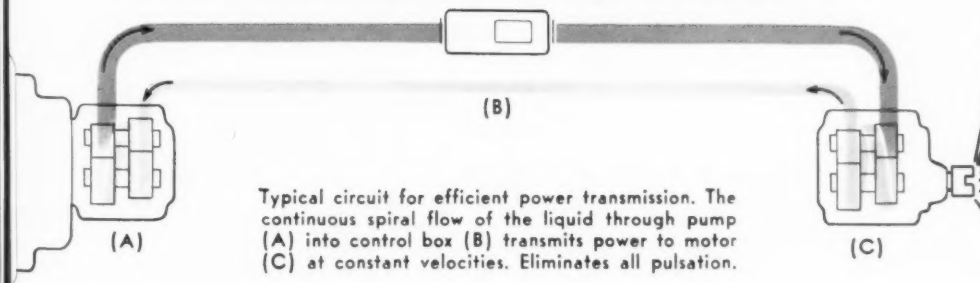


GOES DIRECT TO THE POINT OF POWER APPLICATION



Typical circuit for efficient power transmission. The continuous spiral flow of the liquid through pump (A) into control box (B) transmits power to motor (C) at constant velocities. Eliminates all pulsation.

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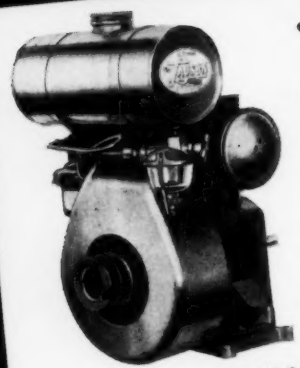

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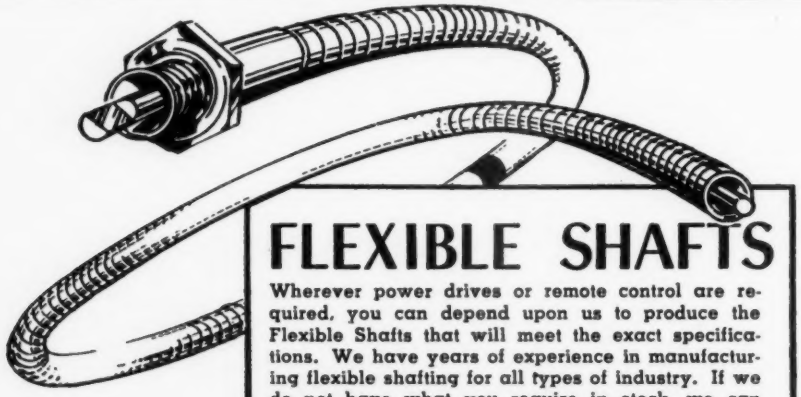

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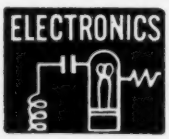

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mulas seems to be impaired by an error in derivation.

The term c, orifice discharge coefficient, is the product of c_c, coefficient of contraction, and c_v coefficient of velocity. Its use in the first formula appearing in the article is incorrect because this formula is a velocity relation only. Furthermore, if the correct coefficient, c_v, were used, it would logically appear in the denominator of the right side of the equation instead of in the numerator.

By using c_v in the first equation

$$\frac{144p}{\gamma} = \frac{V^2}{c^2v\ 2g}$$

and c_c in the continuity equation

$$V = \frac{Av}{c_c a}$$

equation (1) of the article becomes

$$-W\frac{dv}{v} = \frac{\gamma A^2 ds}{c_c^2 c_v^2\ 3456\ a^2}$$

$$-W\frac{dv}{v} = \frac{\gamma A_2 ds}{c^2 3456\ a^2}$$

or

Here c^2 appears in the denominator of the basic equation and not in the numerator. Since the remaining formulas are based on equation (1), they contain the same error.

Incidentally, I would be especially interested to know what values of c would be appropriate for these odd shaped orifices.

—Paul A. Harter,
Engineering Division,
Warner Electric Mfg. Co.

Ed.—Author Brown comments as follows:

"The value for c, as used in the article is customary in calculations of this type, especially as they concern recoil mechanisms. This value is the reciprocal of the one familiar to Mr. Harter.

The choice of any particular c probably is determined by the convenience with which it may be used. Where the pressure is known, and it is desired to solve for rate of discharge, as in venturi meters, it is convenient to use a "c" of the type to which Mr. Harter refers. However, in the present case, where velocity is known from the continuity equation, it is most convenient to use the reciprocal "c" in the numerator when solving for pressure:

$$\frac{144p}{\gamma} = \frac{c^2v^2}{2g}$$

"The Naval Ordnance Department recommends these values for c:

1.15 to 1.37 for throttling rods (such as are used in major caliber gun mounts)

1.12 to 1.20 for grooves (such as are used in minor caliber mounts)."